Manuscript 1

BIO-ASSESSMENT WORK

THE RESPONSE OF FISH AND BENTHIC MACROINVERTEBRATES TO AMMONIA TOXICITY IN SALT CREEK

CITY OF LINCOLN, NEBRASKA
SALT CREEK WATER QUALITY STUDIES

April 3, 2000
(Original Date)

Revised June 16, 2000

BIO-ASSESSMENT WORK

THE RESPONSE OF FISH AND BENTHIC MACROINVERTEBRATES TO AMMONIA TOXICITY IN SALT CREEK

Key Findings

The following are Key Findings from the response of fish and benthic macroinvertebrates to ammonia toxicity in Salt Creek which highlights the main points and conclusions. Extensive detail of the bio-assessment program, final results and final conclusions are also presented within this Manuscript.

- The toxicity of ammonia to the biological community in Salt Creek was measured by observing decreases in the number of fish species, the number of minnow species, the number of benthic macroinvertebrate taxa, and the number of fly taxa at sampling sites located downstream from the Theresa Street and Northeast WWTP's.

- There is a summer dose-response relationship between the number of fish species and the number of minnow species at site BSS04 downstream from the Theresa St. WWTP and at site BSS08, downstream from the Northeast WWTP, and ammonia. This relationship shows that the number of species decrease as ammonia concentrations increase

- There was no winter dose response relationship between the number of fish species and the number of minnow species below the Theresa Street and Northeast WWTP's and ammonia.

- Life cycles of the 36 species of fish collected from Salt Creek demonstrate that Early Life Stages are absent from Salt Creek during the time period of October 20 through March 20..

- There is not a relationship between the benthic macroinvertebrate metrics and ammonia in Salt Creek. The USEPA presented data in the Water Quality Criteria Update for Ammonia (1999) that documents that fish are more sensitive to ammonia than are invertebrates

- An evaluation of bio-assessment results from North Carolina, Wyoming, Massachusetts, and Florida shows that a 26% reduction in the value of biological metric, such as the number of species, relative to the value at a control site is a reliable measurement of impact to those species.

- The dose-response relationship shows that the number of fish species and the number of minnow species in Salt Creek will not decrease by more than 26% if the 30-day average ammonia concentration is not more than 2.1 mg/L.

1.0 INTRODUCTION

Biological assessments were conducted in Water Quality Standards (WQS) Segment LP2-20000 of Salt Creek (SCWQS), Nebraska from June 1994 through October 1999. During this period, six bio-assessments were conducted in the summer and five bio-assessments were conducted during the winter. The technical objective of the SCWQS was to characterize the condition of the biological community in the Creek and to identify some of the major limiting factors to the community. Channnelization, high ambient chloride concentrations, and effluent ammonia discharged from two Lincoln, Nebraska municipal wastewater treatments plants (WWTP's) were identified as possible limiting factors.

Since 1998, the City of Lincoln and their team of consultants (Brown and Caldwell, EA Engineering, and CH2M Hill) have been evaluating ways to use bio-assessment results to derive site-specific ammonia criteria for Segment LP2-20000. In 1999, the Water Environment Research Foundation (WERF) began a peer review of the SCWQS. The Peer Review Panel evaluated the scientific defensibility of the bio-assessment methods and the data interpretation. The reviewers made several suggestions to strengthen the data interpretation. These suggestions included evaluating the results of each bio-assessment event separately; focusing the analyses on the summer collections when ammonia is most toxic; using biological metrics that demonstrate a dose – response relationship to pollution; and evaluating the results empirically. In this document, we discuss how we applied the guidelines provided by the Peer Review Panel to derive site-specific ammonia criteria for ammonia in Segment LP2-20000.

2.0 SITE DESCRIPTION

Salt Creek is a fourth-order tributary to the Platte River in southeast Nebraska (Figure 2-1). For 21.6 miles Segment LP2-20000 flows through Lincoln, Nebraska and rural agricultural land in Lancaster County; and extends from the confluence with Beal Slough to the confluence with Rock Creek. The stream is channelized for flood protection, and over 100 storm water outfalls discharge run-off to the stream. In addition, the City of Lincoln's Theresa Street WWTP (design capacity 24.5 mgd; 37 cfs) and Northeast WWTP (design capacity 8 mgd; 12.4 cfs) discharge into the Segment and contribute a significant portion of the total stream flow at median and below conditions. For example, the historical (1967 – 1999) median Salt Creek flow above the Theresa St. WWTP for the summer regulatory season (April – October) is 94.7 cfs; the average summer season Theresa St. WWTP effluent from 1994 – 1999 was 31.4 cfs; therefore, the Theresa St. WWTP would contribute approximately 25% of the combined stream flow during a summer season median flow condition.

In addition, the Creek is heavily influenced by the underlying Dakota Sandstone Formation near the upstream portion of the Segment. Sodium chloride from the formation dissolves in the groundwater contributing to the stream, and chloride concentrations in the range of 1,000 to 2,000 mg/L are common during median flow conditions. As a result, there are multiple stresses to the biological community in the Creek including habitat degradation caused by channelization, chemical pollution from point and nonpoint sources, and naturally high chloride concentrations.

2.1 Sampling Stations

Eight stations were sampled during the Salt Creek bio-assessments (Figure 2-1). Station BSS00 is located in Segment LP2-30000 where the channel has natural meanders and fresh water. All other stations are located in Segment LP2-20000 where the channel has been straightened and the water is saline. Stations BSS01 and BSS1B are located upstream from both treatment plants and were evaluated as site-specific control sites for measuring biological impacts from the plant discharges. River miles (RM) were measured upstream from the confluence of Salt Creek with the Platte River.

BSS00 – RM 37.68. Located in Wilderness Park (county rural area), upstream from the treatment plant discharges and not influenced by channelization or salinity.

BSS1B – RM 34.11. Located in an urban area, upstream from the treatment plant discharges in the channelized and saline reach of the stream. BSS1B-Pseudo (RM 34.52) is located immediately upstream of this station.

BSS01 – RM 31.22. Located in an urban area, upstream from the treatment plant discharges in the channelized and saline reach of the stream.

BSS04 – RM 29.04. Located in an urban area approximately 10,000 feet downstream of the Theresa St. WWTP (RM 30.97) discharge in the channelized and saline reach of the stream. BSS04-Pseudo (RM 28.69) is located immediately downstream of this station.

BSS05 – RM 27.01. Located in a transitional area from urban to rural land use, approximately 21,000 feet downstream from the Theresa St. WWTP in the channelized and saline reach of the stream.

BSS08 – RM 24.16. Located in a rural area approximately 4,600 feet downstream of the Northeast WWTP (RM 25.03) discharge in the channelized and saline reach of the stream. BSS08-Pseudo (RM 23.80) is located immediately downstream of this station.

BSS10 – RM 19.53. Located in a rural area approximately 29,000 feet downstream from the Northeast WWTP discharge in the channelized and saline reach of the stream.

BSS11 – RM 11.77. Located in a rural area approximately 68,000 feet downstream of the Northeast WWTP discharge in the channelized and saline reach of the stream.

3.0 SITE SELECTION FOR CRITERIA DEVELOPMENT

Data from three of the eight stations sampled during the SCWQS were used to develop site-specific ammonia criteria for Salt Creek. The biological condition at the stations located immediately downstream from the Theresa Street (BSS04) and Northeast WWTPs (BSS08) were compared to the condition from the site-specific control station BSS01 to measure degradation in the biota caused by ammonia toxicity.

A site-specific control station was used because there are no saline ecoregional reference streams for Salt Creek (K. Bazata, 1994). Station BSS01 was selected for criteria derivation because it is most similar to Stations BSSO4 and BSS08 with respect to chloride and it is located immediately upstream from the Theresa Street WWTP. The condition of the biota at Station BSS01 incorporated all the factors that were contributed upstream of the WWTP and served as the best site-specific control for the effects of effluent ammonia.

4.0 COLLECTION METHODS

Sample collection was specified in the Sampling and Analysis Plan (SAP) prepared and submitted to the Nebraska Department of Environmental Quality (NDEQ) as part of the July 8, 1994, "Salt Creek Water Quality Studies (SCWQS) and Effluent Management Workplace". Bio-assessment procedures follow the technical guidance provided in the "Rapid Bio-assessment Protocols for Use in Streams and Rivers" (Plafkin *et al*., 1989); Revision to Rapid Bio-assessment Protocols for use in Streams and Rivers: Periphyton, Benthic, Macroinvertebrates, and Fish (USEPA, 1999); the Nebraska Department of Environmental Quality (NDEQ) "Nebraska Stream Classification Study" (NDEQ, 1991); and "Draft Metric Revision for Nebraska Stream Classification Study" (Draft) (NDEQ, 1995).

4.1 Hydraulic/Physical Measurements

Width, depth, and velocity were measured along 3 to 5 cross-sections at each station (Gordon *et al*., 1992). Five cross-sections were completed at each sampling station during the initial bio-assessment in August 1994. Those results demonstrated that hydraulic conditions were fairly uniform at each station and the number of cross-sections was reduced to three for the subsequent bio-assessments. Depth and velocity points were measured at 15 or more intervals for each cross-section. Substrate at each interval was characterized by visual observation as silt/mud, sand, gravel, or hardpan clay. The first cross-section at a station was located at a point where bridges or other man-made structures did not influence the channel shape. The next two cross-sections were located at points 100 and 200 meters upstream from the initial cross section. All measurements and observations were recorded in field books.

4.2 Habitat

Habitat quality was assessed visually and scored on standard field sheets by trained biologists using best professional judgment. Scores were recorded on Habitat Assessment Field Data Sheets developed by Plafkin *et al*. (1989) and modified by Barbour and Stribling (1994) and Environmental Monitoring and Assessment Program (EPA, 1999). Habitat quality was evaluated while performing the hydraulic measurements. At each interval along the transect, substrate was characterized by visual observation and touch, (i.e., silt/mud, sand, gravel, or hardpan clay), and these observations were used in developing the habitat quality scores for bottom substrate/available cover, pool substrate, sediment deposition, and pool variability.

Channel flow status, bank stability, channel alteration, bank vegetative protection, channel sinuosity, and riparian vegetative zone width were estimated visually for five transects at a station. Each transect was 10 to 15 meters wide and separated from other transects by 50 meters. The average condition for the five transects was recorded as the representative condition for the station.

4.3 Overview of Chemical Sample Collection Procedures

Samples were collected for chemical analysis as plug flow. Sample collection was initiated at locations upstream from the Theresa Street and Northeast WWTPs in order to track the quality of the same packet of water as it flowed downstream. The velocity of Salt Creek, as measured at the USGS flow gauging station near the No. 27th Street Bridge, was used to determine travel time and approximate sampling times of the plug at each station downstream of the Theresa Street WWTP.

Chemical samples were collected as spatially composited grab samples across the channel or as single grab samples from the main flow channel of the Creek. Sample containers were placed on ice and transported to the laboratory for analysis. Analyses included ammonia with distillation, nitrate/nitrite, and Total Kjeldahl Nitrogen (TKN). Parameters and method numbers are provided in the following table.

Parameter	Method Number
Ammonia with Distillation	EPA 350.2
Nitrate/Nitrite	EPA 353.2
TKN	EPA 351.3
Chloride	EPA 325.2

Dissolved oxygen (DO), pH, conductivity, and temperature were measured *in situ* with a Yellow Springs Instruments Model 55 Dissolved Oxygen and Temperature meter, Hanna

HI 9210N pH meter, and a Hanna HI 9033 multi range conductivity meter. All measurements were recorded in field books.

4.4 Benthic Community

Benthic samples were collected from all available habitats with a 30-mesh (575 micron) D-frame dip net (Protocol III, USEPA. 1989). In the channelized reaches the habitat types include undercut banks, root wads, overhanging vegetation, and the sand substrate. These habitats were sampled in flowing water and in slack water behind sand bars. Habitat types were proportionally sampled at each of the biological stations for similar time periods and most of the collection time was used to sample the most productive habitats. Individual dip net samples were then combined in a 30-mesh sieve bucket. Composite samples for each station were preserved with 5 to 10 percent formalin solution in plastic jars and returned to EA's biological laboratory for taxonomic identification. Common taxonomic groups, habitat types, sampling conditions, and level of effort were recorded in field notebooks.

The most productive habitats (root wads and the collection of woody debris in the roots) are all along the banks in Segment LP2-20000. Log jams and larger concentrations of woody debris that are preferred habitat for sensitive invertebrates such as mayflies and caddis flies are rare in Salt Creek. Daily observation of these locations during the *in situ* toxicity testing has shown the moving sand substrate buries these preferred habitats. The woody debris may also be scoured out of the channelized reach periodically during high flow events.

Quantitative macroinvertebrate samples were collected during the August 1999 summer bio-assessment only. Artificial multiple-plate substrate samplers (i.e., modified Hester-Dendy) were used as described by the Ohio EPA (Ohio EPA, 1989). Two arrays of five multiple-plate samplers were attached to a metal fence post and placed midway through the water column at each sampling station. All samplers were exposed for a six-week colonization period and retrieved during the August 23 – 27, 1999 bio-assessment. Samplers were visited weekly during the colonization period to remove plastic bags and other large pieces of debris that smothered the samplers, and record depth and velocity near the multiple-plate samplers.

A minimum of 200 macroinvertebrates were identified from each qualitative dip net and multiple plate composite sample. All organisms were identified to the lowest taxonomic level practicable (usually species) in the laboratory using the taxonomic references cited in the "Nebraska Stream Classification Study". After identification, samples were retained in EA's possession for the duration of the project.

4.5 Fish Community

Fish were collected by electro-fishing while wading and seining (Protocol III, USEPA. 1989). The electro-fishing was done with a Coffelt VVP-15 unit mounted in a 12-foot aluminum boat. A standard collection at each station consisted of shocking a 400 to 600 meter length of stream for 30 to 40 minutes. Seine hauls (minimum of two 10 meter hauls) were completed at each station after the electro-fishing had been completed.

All fish collected were identified to species level, if possible. Fish were then weighed, measured, counted, and released on-site. Cyprinids, young of the year, uncommon individuals, and voucher specimens were preserved in 5 to 10 percent buffered formalin and returned to EA's biological laboratory for taxonomic verification. All individuals were examined for deformities, fin erosion, lesions, and tumors on-site. Measurements and observations regarding the condition of the individual fish, as well as sampling conditions, were recorded in field notebooks. Habitat types, level of effort, and sampling conditions were also recorded in field notebooks.

5.0 QUALITY ASSURANCE/QUALITY CONTROL

In order to ensure the repeatability and reproducibility of bio-assessments, quality control parameters of the bio-assessment methods need to be explicitly defined just as they are for chemical and whole effluent toxicity (WET) methods (Grothe et al 1997). Quality assurance and control with bio-assessments in Salt Creek began with the careful planning and staffing of the SCWQS project as documented in the "Salt Creek Water Quality and Effluent Management Studies Work Plan" (City of Lincoln, July 1994). Experienced biologists and technicians performed each of the eleven bio-assessments performed on Salt Creek, and collections followed written standard methods and qualified taxonomists using standard reference texts complete taxonomic identifications of collected fish and macroinvertebrates. All field data were recorded in bound, standardized field books in a consistent manner between sites and sampling events and field notes were reviewed and verified after each sampling event. EA personnel independently verified data entry, calculations, and text. These procedures performed for each bio-assessment cover the four areas of the Quality Assurance/Quality Control (QA/QC) Project Plan recommended by Grothe (1997): (1) project management; (2) measurement/data acquisition; (3) assessment/oversight; and (4) data validation and usability.

5.1 Chemistry

The SCWQS were designed to provide information about a wide range of chemical constituents in the stream. The QA/QC protocols used in the study conform to the procedures described in the NDEQ, Water Quality Division publication titled "Procedures for Developing Wasteload Allocations," (May 1992). Regulatory Management, Inc. of Colorado Springs, Colorado monitored and periodically audited the quality control (QC) procedures. The quality control samples that were used to identify potential problems with individual components of the analytical system included:

- Travel Blanks
- Field Blanks
- Field Duplicates
- Inter-laboratory Duplicates

The total number of external QC analyses performed equaled 18 percent of all samples collected. In addition, duplicate samples were collected for 5 percent of all samples and one field blank was collected each week. Chemical data collected during the SCWQS were used to characterize Salt Creek and were used in conjunction with bio-assessment results.

5.2 Precision, Accuracy, Representativeness, Completeness and Comparability

Assessment of precision, accuracy, representativeness, completeness and comparability (PARCC) parameters is imperative to maintaining high quality data. A description of the application of PARCC's to the SCWQS biological assessments is discussed below by parameter.

5.2.1 Precision.

Precision is defined as the level of agreement among repeated measurements of the same characteristic (USEPA 1996). Precision of the bio-assessments completed for the SCWQS can be measured as the coefficient of variation (CV) of the habitat, species richness, native Cyprinid richness, taxa richness and Chironomidae richness metric values at the eight stations representing six discrete summer collections. Low variances among the collections at a sampling station indicate a consistent biological community at the eight sampling stations. If variances were high, it would indicate a changing community or inconsistent sampling at a station. Precision is ensured by an effective study design implemented to minimize and identify sources of data variability. Also, one investigator has managed all bio-assessments performed on Salt Creek.

The CV's for the habitat values from the SCWQS range from 4% to 11% and the fish metric values ranged 13% to 40% for species richness and 28% to 49% for native Cyprinids. CV's for the macroinvertebrate community ranged from 8% to 34% for taxa richness and 12% to 42% for Chironomidae richness (Table 5.2.1-1). The high CV's observed for the native Cyprinid metric is discussed further in Section 5.2.4. For comparison, Barbour et al (1996) reported the CV's for individual benthic macroinvertebrate metrics and the combined Stream Condition Index for collections from Florida reference streams. This analysis used seven replicate sites. The CV's in Barbour's work for individual metrics ranged from 11% to 34% and was 7% for the overall SCI. These data are similar to Salt Creek results and corroborate the relatively low variability of bio-assessment results when the data are collected by standard protocols and experienced biologists.

Table 5.2.1-1 Habitat, and Biological Metric Scores

Biological Component	Sampling Stations							
	BSS00	**BSS1B**	**BSS01**	**BSS04**	**BSS05**	**BSS08**	**BSS10**	**BSS11**
Habitat %	4	6	8	11	8	3	6	5
Species Richness %	14	13	17	21	27	40	29	18
Native Cyprinids %	42	28	40	31	29	49	43	33
Taxa Richness %	8	21	26	26	34	26	25	18
Chironomidae Richness %	42	22	33	19	30	28	12	30

In contrast, whole effluent toxicity (WET) tests and chemical-specific analyses (CSC) conducted by NPDES permittees for compliance monitoring in North Carolina include information for the fathead minnow growth endpoint and the *Ceriodaphnia* reproduction endpoint. The CV's for these sublethal endpoints range from 27% to 43% and the CV's for six of eight chemical parameters exceed the values for the sublethal toxicity test endpoints.

The limited variability of bio-assessments relative to chemical analyses and toxicity testing is based on three elements of data collection and interpretation of bio-assessments (Burton et al 1996):

(1) Variability is compressed through the use of multimetric interpretation that builds some redundancy into the data interpretation;

(2) Variability is stratified because of the interpretation of the data from a site is within the context of an ecological classification of sites. For example, the biological expectation for Segment LP2-20000 is based on its classification as a warm water stream located in eastern Nebraska with flow greater than 25 cfs and a sand substrate;

(3) Variability is controlled through the use of standardized sampling procedures that address seasonality, level of sampling effort, selection of sampling habitats, selection of sampling gear, and spatial distribution of sites.

The variability of bio-assessments in general, and the Salt Creek bio-assessment in particular, is limited because an effective study design was implemented carefully and consistently by professional biologists. A well-executed bio-assessment is not inherently more variable than WET testing or chemical analyses. It is concluded from the discussion provided above that bio-assessment is the best measurement for biological impact in Salt Creek, and there are few restrictions on the interpretations of the bio-assessment results relative to the information provided by chemical criteria and toxicity testing (Mount 1994).

5.2.2 Accuracy

Accuracy is the difference between an estimate based on the data and the true value of the parameter (USEPA 1996). Yoder (1995) evaluated accuracy and the interpretation of biological assessments using Rapid Bio-assessment Protocols III (macroinvertebrates) and IV (fish) as follows:

Factor	Rank
Ecological Complexity	High
Environmental Accuracy	Moderate to High
Discriminating Power	Moderate to High
Policy Restrictions	Few

Ecological complexity, which measures the ecological dimensions inherent in the basic data or the scope of ecological complexity, was ranked high. The data and its interpretation is holistic based on the existing communities and does not require extrapolation or the use of surrogates. Environmental accuracy was ranked moderate to high. Environmental accuracy is the ability of the ecological endpoints (metrics) to differentiate conditions along an environmental gradient. The identified gradient in Salt Creek is above and below the point source discharges of the WWTP's. Discriminating power was ranked moderate to high and is the power of the data to discriminate between different subtle effects in the biological community. The power of the metrics is that they incorporate community attributes into measurements for biological assessment of the biological condition. Policy restrictions were ranked as few. Policy restrictions refer to the relationship of biological assessment to chemical-specific criteria, WET testing, or other surrogate indicators of aquatic life use attainment; meaning that there are few constraints on the interpretation of biological assessment data relative to the other surrogate measurements.

5.2.3 Representativeness.

Representativeness has multiple meanings for the Salt Creek bio-assessments. On one hand, the issue is how well the bio-assessments represent the condition of the community. That issue has been addressed by the sampling design. Two important assemblages (fish and macroinvertebrates) were sampled during base flow conditions in summer and winter over a six-year period. Sampling was completed at a least disturbed station (BSS00), at site-specific control stations for salinity and channelization (BSS1B and BSS01), and two potential impact stations downstream from each WWTP (BSS04, BSS05, BSS08, and BSS10). Using this design, variability in the results because of assemblage, season, year, or location can be characterized and the bio-assessment results are representative of Salt Creek.

Representativeness and sufficiency of taxonomic analysis for benthic macroinvertebrates (qualitative dip net sample) were assessed in 1997 by comparing number of invertebrate taxa and number of Chironomidae taxa for: (1) a 200 organism subsample, and (2) for all the organisms collected from established and pseudoreplicate stations. This exercise tested whether the sample design and methods used for macroinvertebrate analysis resulted in a sample that was truly representative of the indigenous benthic macroinvertebrate community in Salt Creek.

All organisms collected and a 200 organism sub-sample were identified for station BSS1B and its pseudoreplicate station (Appendix A; Table A-5). Counts for taxa richness and Chironomidae richness between BSS1B and its pseudoreplicate and between the 200 subsample count and total counts differed by less than 10 percent. At station BSS08 and its pseudoreplicate there were less than 200 organisms in the sample. These limited data indicate that the 200 organism sub-sample was sufficient for characterizing macroinvertebrates in Salt Creek.

The second issue of representativeness concerns which component of the biological community in Salt Creek is most sensitive to ammonia toxicity and most representative of ammonia impacts. Fish are more sensitive to ammonia than invertebrates and the response of the fish community will be the primary measure of ammonia impacts. USEPA (1999) reported that ammonia was acutely toxic to 19 invertebrate species in the range of 25.8 to 388.8 mg N/L and acutely toxic to 29 species of fish in the range of 12.11 to 51.06 mg N/L. The upper and lower bounds of the range of effect concentrations for the fish are an order of magnitude less than the bounds on the range of values for the invertebrates.

5.2.4 Comparability.

Comparability or Repeatability of the biological data collected at Salt Creek sampling sites was assessed by the collection of “pseudoreplicate” samples (USEPA, 1997b). Assuming the controllable factors of the bio-assessment are controlled (sampling personnel, equipment, date and stream discharge) and habitat is similar to previous bio-assessments, the comparability of the data is addressed by sampling a “duplicate” stream segment adjacent to an existing sampling station on Salt Creek.

5.2.4.1 Pseudoreplicate Sampling Of Fish And Invertebrates

Pseudoreplicate samples were collected during a winter bio-assessment performed on March 5 – 8, 1997 and a summer bio-assessment performed on August 24 – 27, 1999. Pseudoreplicate sampling is consistent with NDEQ Data Quality Objectives (DQOs) for environmental monitoring projects and the second edition of the Rapid Bio-assessment Protocols (USEPA, 1999), which emphasize Performance Based Monitoring Systems. The representativeness and repeatability of the collections were evaluated by sampling a “duplicate” location adjacent to an existing sampling station.

5.2.4.2 Station Locations

During the winter event, pseudoreplicate stations were located near stations BSS1B and BSS08 (Figure 2-1). The pseudoreplicate stations for BSS1B and BSS08 were also sampled during the summer 1999 bio-assessment along with a pseudoreplicate for station BSS04. All collections were performed at the pseudoreplicate stations immediately after sampling the established biological sampling station and the same field crew completed all sampling. Sampling methods used were as described in Sections 4.1 – 4.5.

5.2.4.3 Repeatability of the Winter Collections

The results of the hydraulic measurements, biometrics, and habitat scores were compared between established sampling stations and its pseudoreplicates. Biometrics included macroinvertebrate taxa richness, Chironomidae richness, fish species richness, and native Cyprinids species richness. The similarity of the samples was evaluated as the percent of change of the parameter from the established station to the pseudoreplicate (Table 5.2.4.3-1). A more detailed summary of the winter pseudoreplicate data is provided in Appendix A (hydraulic measurements, Tables A-1 and A-2; March 1997 fish collections, Table A-3; habitat scores, Table A-4; and March 1997 macroinvertebrate collections, Table A-5).

Table 5.2.4.3-1 Summary of Data Collected at Established and Pseudoreplicate Stations, Salt Creek, March 6-7, 1997

Parameter	BSS1B	Pseudo	% Change	BSS08	Pseudo	% Change
Average Width	136 ft	83 ft	39	108 ft	102 ft	5
Average Depth	0.76 ft	1.58 ft	108	1.42 ft	1.51 ft	6
Average Velocity	1.11 fps	0.94 fps	15	1.30 fps	1.23 fps	5
Average Discharge	127.8 cfs	125.5 cfs	2	202.5 cfs	207 cfs	2
Habitat Quality	103	102	<1	91	89	2
Fish Species Richness	8	8	0	10	9	10
Native Cyprinids	5	3	40	7	7	0
Macroinvertebrate Taxa Richness	20	21	5	17	16	6
Chironomidae Richness	12	11	8	15	11	26

As an average, the water at the pseudoreplicate for station BSS1B was twice as deep as it was at BSS1B (108% difference) and this is the greatest difference among the parameters compared during the winter sampling. As expected, the width of the wetted channel was 39% less at the deeper pseudoreplicate station. In addition, 40% fewer cyprinid taxa were collected at the pseudoreplicate station. Many cyprinid species prefer shallow streams with sandy substrates, and the shallower depths at station BSS1B may have provided better habitat for the cyprinids (Pflieger, 1975).

Eight of nine parameters varied by 10% or less between BSS08 and the pseudoreplicate. The number of chironomid taxa differed by 26% between stations. Barbour *et al*. (1996) reported coefficients of variation of 11.4% for the number of macroinvertebrate taxa and

23.7% for the number of Choronomidae taxa for seven replicate stations from Florida. The variability of the macroinvertebrate collections from Salt Creek and the replicate stations in Florida is similar. This similarity indicates that the repeatability of the Salt Creek collections was consistent with the variability of the collection method.

5.2.4.4 Repeatability of Summer Collections

During the summer, hydraulic measurements and habitat scores were fairly consistent for all three pairs of stations Table 5.2.4.4-1, Appendix A, and Tables A-1, A-2, A-4, A-6, and A-7). For these parameters, the percent change was less than or equal to 11% for 13 of 15 parameters. Average velocity and average discharge varied by 25% and 27% between BSS1B and its pseudoreplicate, respectively.

Table 5.2.4.4-1 Summary of Data Collected at Established and Pseudoreplicate Stations, Salt Creek, August 24-27, 1999

Parameter	BSS1B	Pseudo	% Change	BSS04	Pseudo	% Change	BSS08	Pseudo	% Change
Ave. Width, ft.	86	78	9	122	123	1	108	102	6
Ave. Depth, ft.	0.51	0.54	6	0.94	0.97	3	1.37	1.43	4
Ave. Velocity, fps	0.96	0.72	25	1.20	1.16	3	1.41	1.30	8
Ave. Discharge, cfs	44.3	32.4	27	136.6	146.9	7	207.5	185.1	11
Habitat Quality	97	100	3	99	99	0	107	106	<1
Species Richness	12	13	8	9	6	33	6	7	16
Native Cyprinids	5	1	80	2	2	0	2	3	50
Taxa Richness	40	46	15	34	31	8	38	36	5
Chironomidae Richness	12	15	25	10	10	0	15	19	26
Quantitative Macroinvertebrate[1]									
Taxa Richness	29	28	4	22	28	27	20	25	25
EPT Taxa	12	13	8	10	11	10	7	6	140
Chironomidae Richness	13	10	30	8	11	37	8	12	50

1. Macroinvertebrates collected from composited multiple-plate samplers.

Among the biometrics, the number of cyprinid species was the most variable metric, as was true for the winter collections. The number cyprinids varied by 80% for station BSS1B and its replicate, 0% for BSS04 and its replicate, and 50% for BSS08 and its replicate. It is expected the cyprinids will show the greatest overall change because a change in 5 (BSS1B) or 2 (BSS04 and BSS08) species results in a large relative change. The number of fish species, invertebrate taxa, and chironomid taxa all differed by less than 33% among the three pairs of stations.

Frenzel and Swanson (1996) reported the results of collections from nine streams in the Platte River Basin of Central Nebraska during the summer. All these streams have sandy substrates with fish communities dominated by cyprinids. Frenzel and Swanson collected fish from multiple reaches within a station. Maximum observed differences in species richness for three replicate reaches were 33% for the Dismal River, 10% for the Platte River, and 18 percent for Maple Creek. Maximum observed differences in native Cyprinids richness for three replicate reaches were 25% for the Dismal River, 28% for the Platte River, and 14% for Maple Creek. From these levels of precision the authors concluded, *"These data indicate that the original reach sampled was representative and, therefore, conclusions regarding status of local conditions could be made with confidence"*. A comparison to Frenzel and Swanson's results indicate that the number of fish species reported for the summer collections were representative of Salt Creek. In contrast, the number of native cyprinid species was variable, and the sources of the variability have not been identified.

Overall, the pseudoreplicate sampling shows that hydraulic measurements, habitat quality scores, and the taxa richness for fish and macroinvertebrate collections were representative of the conditions in Salt Creek at the time of sampling during winter and summer. Measurements of water depth and the number of cyprinid species were more variable.

5.2.4.5 Repeatability of Quantitative Macroinvertebrate Collections

Quantitative macroinvertebrate samples were collected on multiple-plate samplers during the summer 1999 bio-assessment (Table 5.2.4.3-1 and Appendix A, Table A-8). Multiple-plate samplers were used: (1) to obtain a quantitative sample of macroinvertebrates from Salt Creek and (2) to assess the biases of qualitative dip net sampling. Macroinvertebrate metrics used to assess repeatability and representativeness of the biological assessment methods include taxa richness, Chironomidae richness, and EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera).

Taxa richness of macroinvertebrates collected on the multiple-plate samplers ranged from 20 to 29 taxon. Variability of taxa collected between the established station and there pseudoreplicate ranged from 4 to 27 percent. For EPT richness, 6 to 13 taxon were collected and the variability of the number of taxa collected between the established station and the pseudoreplicate ranged from 8 to 14 percent. Chironmidae taxa richness were the most variable metric, ranging from 11 to 50 percent between the established station and the pseudoreplicate station. There is more variability for the multiple-plate samplers (8 to 50 percent) then for the qualitative samples (0 to 26 percent).

Fewer taxa were collected on the multiple plate samplers then collected by dip net sampling. The number of taxa collected by dip-net sampling ranged from 31 to 46 taxon. Taxa collected on the multiple-plate samplers ranged from 20 to 29 taxon. Chironomidae and EPT taxa comprised 37 to 63 percent of the qualitative samples and from 72 to 86 percent of the multiple-plate samples of the taxa collected. The multiple-plate samplers tend to be more selective for taxa which colonize hard substrates and are also rheophilic (Ephemerotera and Trichoptera). Dip-net sampling from all available habitats was more representative and complete with respect to the total number of macroinvertebrate taxa and the number of chironomid taxa.

5.2.5 Completeness.

A comparison of fish collection results for the SCWQS to those of previous researchers was used to assess completeness of the biological samples collected from Salt Creek.

Five scientifically sound collections of fishes from the Salt Creek basin and/or the Lower Platte River basin were identified. One of the goals of the SCWQS was to objectively characterize the fish and macroinvertebrate communities in Salt Creek using standardized scientific methods. Collections have been performed during the summer and winter seasons. All available natural habitat has been sampled by electrofishing and seining.

Forty species of fish have been collected from Salt Creek between Pioneers Blvd. and Greenwood by three different investigators: (1) Bliss and Schainost (1973); (2) Maret and Peters (1977); and (3) City of Lincoln (1994-1999). This species count is based on collections from sampling locations that could be verified in the literature. Maret and Peters (1977) performed a comprehensive survey of fish in the Salt Creek basin. Thirty-four species of fish were collected in the basin while 24 species were collected in the Segment from Pioneers Blvd. to Greenwood. Bliss and Schainost (1973) collected 45 different species of fish from the lower Platte River basin and twenty-three were collected in the Segment of Salt Creek from Pioneers Blvd. to Greenwood. The City of Lincoln has collected thirty-six species of fish in the same segment.

These comparative results show that the City of Lincoln has conducted a comprehensive and complete assessment of the fish community in Salt Creek. A total of 40 different species have been collected from the Segment of interest and 36 of these species were collected during the SCWQS. Moreover, 11 more species were collected from the reach during the SCWQS than during any other investigation. Also, sampling of the macroinvertebrate community in Salt Creek by the City of Lincoln has resulted in the collection of 187 taxa representing 51 families.

6.0 METHODS FOR DATA ANALYSES

6.1 Candidate Metrics for Responses to Gradients of Human Influence

A variety of metrics were evaluated as measures of an ecological response to human disturbance (Table 6.1.2-1). These categories of metrics included taxa richness, taxa composition, indicator taxa richness, tolerant/intolerant taxa richness and abundance, trophic function metrics, and biotic indices (ibid, Resh and Jackson, 1993; Simon and Lyons, 1995).

It was concluded that taxa richness metrics were best for measuring impact after a review of the literature about the response of metrics and a review of the Salt Creek data (Table 6.1-1). Karr and Chu (1999) evaluated biological monitoring techniques and concluded that a decline in taxa richness is a reliable response to human degradation for many groups of aquatic organisms. The authors cited investigations that have established this relationship for river fish (Karr 1981, Miller *et al*, 1988; Ohio EPA 1988; Rivera and Marrero 1994; Rodriguez-Olarte and Taphorn, 1994; Lyons *et al*. 1995 and 1996; and Koizumi and Matsunaya, 1997) and freshwater macroinvertebrates (Ohio EPA 1988, Ryenolds and Metcalfe-Smith, 1992; Kerans and Karr 1994; DeShon 1995; Fore *et al*, 1996; and Thorne and Williams, 1997).

Table 6.1-1 Metrics Evaluated for Response to Gradients of Human Influence

Macroinvertebrate Metric	Potential Problem with Metric
Taxa Richness	None
EPT Richness	Variable response to gradient of Influence [1]
Chironomidae Richness	None
Biotic Index	Figure 6.1
EPT/Chironomidae Ratio	High variance of ratios[2]
Percent Dominant Taxa	Figure 6.1
Scraper:Collector-Filterer Ratio	High variance of ratios[2]
Jaccard Index	Lack of saline influenced reference site[3]

Fish Metric	Potential Problem with Metric
Species Richness	None
Number of Individuals	Highly Variable[4]
Native Cyprind Richness	None
Number of Intolerants	No intolerants species in Salt Creek[4]
Percent of Tolerants	Figure 6-1
Percent of Omnivores	Figure 6-1
Percent of Insectivores	Not sensitive to poor water quality within ecoregion[5]
Percent of Delts	Highly variable within ecoregion – Salt Creek[4]

[1] Donley, 1991
[2] Karr and Chu, 1999
[3] Bazata 1999
[4] SCWQS 1996 and 1997
[5] Frenzel and Swanson, 1996

Resh and Jackson (1993) evaluated the accuracy of various macroinvertebrate metrics for data collected by rapid bio-assessment methods. They defined accuracy as detecting impacts to the macroinvertebrates when they occur and not detecting impacts when they do not occur. These authors reported that richness metrics were consistently accurate. Finally, Dickson and Waller (1992) reported that fish and macroinvertebrate richness are consistently important variables for establishing the relationship between toxicity and an ambient biological response. The findings of Dickson and Waller are important because our goal is to derive a relationship between taxa richness and ammonia toxicity in Salt Creek.

The taxa richness of the Salt Creek summer fish community is comprised of 33 species of fish representing 8 different families (Table 6-1 and Table 7-3). Also, the macroinvertebrate community of Salt Creek is represented by 187 taxa representing 51 families. Of the 33 species of fish collected five were classified as “exotics” (gambusia, walleye, bighead carp, goldfish and brook silverside) and were not included in the fish richness metrics. The removal of these five species of fish was based on professional judgement with NDEQ personnel. NDEQ collections of fish inhabiting streams in the

Western Corn Belt Plains ecoregion which is inclusive of Salt Creek was also used to define species which are representative of Salt Creek and the ecoregion (Table 6-1; NDEQ, 1991; Omerik, 1987). Twenty-eight species of fish, including 11 native Cyprinid species were identified as being critical components of the fish community in Salt Creek.

6.1.1 Data Sources

Biological data collected by NDEQ staff for the surface water-monitoring program were used to evaluate the response of (1) the number of fish species, (2) the number of native cyprinid species, (3) the number of macroinvertebrate taxa (generally genera), and (4) the number of chironomid taxa (generally genera) to a gradient of human influence. Data were selected from the State of Nebraska biological database which represent varying levels of human influence. Data sources included the 1996 and 1998 "Nebraska Water Quality Report" (305b); the 303d list of Impaired Waters for 1996 and 1998; the 1991 and 1995 Nebraska Stream Classification reports; and electronic data files containing biological collections from sites throughout Nebraska. From this search, three classes of streams or levels of human influence were identified in eastern Nebraska; reference streams, channelized streams and ammonia impacted streams (Table 6-2)**.** Variables, which may confound the comparison (i.e. different ecoregions, other impacts, different aquatic life use classification, etc.), were minimized for the selected streams. All streams used for this analysis are influenced by agricultural non-point sources.

Six reference streams were identified from the State database. All of these streams were designated State reference streams for fish, macroinvertebrates, and habitat quality by the NDEQ. All of these streams are; (1) in eastern Nebraska, (2) located in the Western Corn Belt Plains Ecoregion, (3) designated to support Warmwater A aquatic life, and (4) reflect minimal human influence for this region. The six reference streams do differ somewhat in drainage area, base flow, substrate type, and vegetation.

Four channelized streams were identified in the State database. These streams were selected because channelization exists without other sources of degradation, aside from agriculture.

Two ammonia-impacted streams were identified in the State database. Ammonia streams were identified as being degraded by un-ionized ammonia in the 1996 and 1998 303d list. Although the biological collections were made downstream from municipal WWTP's in these ammonia degraded streams, no effluent or ambient chemical monitoring for ammonia was available for these sites.

6.1.2 The Response Of Richness Metrics To Human Influence In Eastern Nebraska

The response of the four metrics in the three kinds of streams is presented in Table 6.1.2-1 and Figure 6-2. The number of observations for the combinations of metrics and stream condition varies widely. There are 13 observations for each of the fish metrics at reference sites, four observations in channelized streams, and two observations in ammonia-impacted streams. There are 5 and 6 observations for the invertebrate metrics at reference sites, 3 and 4 observations in channelized streams, and 1 and 2 observations in ammonia-impacted streams. Based on the number of observations alone, the fish metrics may provide a more reliable response to degradation in eastern Nebraska.

Table 6.1.2-1 Average Metric Values, Standard Deviations, and Number of Observations (N) – (also see Figure 6-2).

Metric	Metric Values by Stream Type & Observations (N)		
	Reference	**Channelized**	**Ammonia Impacted**
Fish Species Richness	10.1 ± 1.6 (13)	6.5 ± 1.3 (4)	4 ± 2.8 (2)
Native Cyprinid Species	4.8 ± 1.5 (13)	4.7 ± 0.9 (4)	1.5 ± 0.7 (2)
Invertebrate Taxa Richness	40.2 ± 14.8 (6)	21 ± 9.5 (3)	18 ± 0 (2)
Chironomidae Richness	13.2 ± 3.5 (5)	6.7 ± 3.5 (4)	1 ± 0 (1)

The metric, fish species richness, was capable of discriminating between all three classes of streams. The number of species declined by 35% in channelized streams and by 60% in streams with elevated ammonia. Native cyprinid richness did not discriminate between a reference and channelized streams. This would be expected, since cyprinids prefer shallow streams with sandy substrates created by channelization. The number of native cyprinids declined by 70% in ammonia-impacted streams relative to the reference streams.

The number of macroinvertebrate taxa declined by approximately 50% in the channelized and ammonia-impacted streams relative to reference streams. For these data, macroinvertebrate taxa richness was similar in ammonia-impacted and channelized streams. Chironomidae richness was capable of partitioning between all three classes of streams used for this analysis. However, this conclusion is tentative because of the limited amount of data.

6.2 Assessment of Impairment to the Biological Community

Impairment assessment requires an objective approach to determine change in the biological community. Diamond *et al.* (1999) evaluated the relationship between Whole Effluent Toxicity (WET) test results and in-stream impairment. This study demonstrated that Relative Difference (RD) between upstream and downstream biological metric values was a reliable way to determine in-stream impact from WWTP discharges. Relative Differences were calculated as:

(*upstream metric score (MS) – downstream MS*) / (*upstream MS + downstream MS*)

RD scores range from –1.0 to +1.0, where a positive value indicates a decrease in the metric at the downstream site. A value near 0.0 indicates little or no difference between the upstream and downstream conditions. Diamond and his coworkers studied data from Plafkin *et al*. (1989), North Carolina DHNR (1990), and more recent analyses by Tetra Tech, Inc. of benthic macroinvertebrate assessments in Florida, Wyoming, and Massachusetts. Their report suggests that various sampling and analysis methods typically classify a site as impaired if the metric values at the site are less than 70 percent of reference station values. The authors also showed that the distribution of RD values for sites downstream from effluent discharges in Ohio, Virginia and Kentucky was similar, despite differences in bio-assessment methods among state programs. Diamond *et al*. evaluated the data from 43 sites in North Carolina. They reported that the state only identified 2.5% of the sites as impaired that would have been identified as unimpaired using an RD value of 0.15; therefore, 97.5% of the sites were successfully classified (p<0.01).

Sensitivity analysis for RD threshold values of 0.12, 0.15, and 0.17 which equate to 21, 26 and 29 percent differences, respectively, was conducted with data from a total of 100 sites in North Carolina, Ohio and Virginia. Slight differences were observed in the percentage of sites judged as impaired (4% to 12%) depending on whether the threshold values of 0.12 or 0.17 were used as opposed to the 0.15 threshold value. These differences indicate that the potential misclassification rate, based on the threshold value itself, was small. Therefore, using 0.15 as the impairment threshold is subject to a small degree of uncertainty (less than or equal to 12% misclassification error).

An RD equal to 0.15, which equates to a 26% reduction in the metric value observed at the control station, was used as the threshold value for determining impairment at the stations downstream from the Theresa Street and Northeast WWTPs on Salt Creek. This value was used for fish and invertebrate metrics although Diamond etal. only used RD = 0.15 to relate WET results to the in-stream response with macroinvertebrate metrics. A 26% reduction in a fish or macroinvertebrate metric is similar to the 20% reduction in growth, reproduction and survival that is used as the threshold for chronic toxicity in the 1999 USEPA Revised Ammonia Criteria Update. The goal of this evaluation is to determine the toxicity response of the indigenous community to ambient ammonia and select a protective criteria based on that response. Because of the similarity of the impairment thresholds for indigenous macroinvertebrate communities to toxicity (Diamond et. al.) and for fish and macroinvertebrates to the chronic toxicity of ammonia (USEPA), RD=0.15 is an appropriate threshold for both communities for this toxicant.

6.2.1 Calculation of Relative Differences

Relative differences were calculated for stations BSS04 (downstream from the Theresa St. WWTP) and BSS08 (downstream from the Northeast WWTP) separately. The metric value (fish species richness, native cyprinid richness, macroinvertebrate taxa richness, and chironomid richness) from BSS01 (site-specific control station) was compared to the corresponding values from BSS04 and BSS08 for each bio-assessment event. The value for the metric at the site-specific control station represents the response for the metric in the saline, channelized reach of the stream, exclusive of impacts caused by the WWTP effluents.

6.2.2 Estimation of Protective Ammonia Levels

A continuous simulation model of total ammonia concentrations in Salt Creek was used to estimate the highest 30-day average and the highest daily total ammonia concentrations. The modeling is discussed in *Manuscript 3 Salt Creek Ammonia Modeling*.

Total ammonia values were analyzed as an independent variable, and RD values were analyzed as a dependent variable in linear regressions with the summer bio-assessment data. Total ammonia was expressed as the highest 30-day average and daily maximum concentration observed for 30, 60, 90, and 180-day periods prior to each bio-assessment. In addition, the 95th percentile values for the 30-day average and daily concentrations were evaluated for each time period (Table 6-3). The combinations of variables evaluated in the regressions of the metric response to ammonia is shown in Table 6.2.2-1. The variables included RD values for each metric and measurements of maximum ammonia concentrations for four exposure periods for six years.

A protective ammonia concentration for Salt Creek was selected by identifying the concentration in the regression associated with the intersection of the total ammonia/RD regression line and RD = 0.15.

Table 6.2.2-1 Variables Evaluated in the Regressions of the Fish Metric Relative Difference Values and Ammonia

Relative Difference Values	Data Sets (Years)	Metrics	Ammonia Values (mg/L)	Exposure Period (Days)
BSS01 vs. BSS04	1994	Fish Species	Highest 30-day Average	30
BSS01 vs. BS008	1995	Native Cyprinid Species	Highest Daily	60
	1996	Macroinvertebrate Taxa	95% 30-day Average	90
	1997	Chironomid Taxa	95% Daily Value	180
	1998			
	1999			

7.0 RESULTS

7.1 Comparisons of Physical and Chemical Conditions among Stations

The hydraulic measurements, habitat scores, and chemical parameters were evaluated to determine the similarity of the physical and chemical conditions at the site-specific control station (BSS01) and the potentially impacted stations (BSS04 and BSS08). Differences in these variables among stations may cause changes in the biological community that would confound the interpretation of effects caused by ammonia toxicity. Conversely, the similarity of these variables among stations strengthens the assessment of ammonia impacts if ammonia is the only variable that changes significantly among the stations. The variables of interest include water depth, velocity, wetted stream width/depth ratios, habitat quality, substrate types, temperature, pH, dissolved oxygen, conductivity/chlorides, and total ammonia. The data were collected during the six summer bio-assessments.

7.1.1 Hydraulics and Habitat Quality

The hydraulic data were similar among stations, and the hydraulic conditions reflect the effects of channelization. Among the three stations, 80-95% of the depth measurements were less than 1.5 feet (Figure 7-1). For velocity, 70 – 80% of the measurements were greater than one foot per second (fps). Channel geometry is also similar among stations. Median width-to-depth ratios range from 95:1 at BSS08 to 159:1 at BSS01. As a matter of perspective, depths at BSS00, in the meandering reach of the stream, were distributed fairly evenly at half-foot intervals between 0 and 2.5 feet (Brown and Caldwell *et al*. 1997). Eighty percent of the velocity measurements at BSS00 were between 0 and 0.5 fps, and the median width-to-depth ratio was 31:1.

Median habitat quality scores ranged from 82 (BSS01) to 106.5 (BSS08), with a maximum possible value of 200. Habitat quality was judged to be poor, because of the predominance of uniform depth and velocity; homogenous, unstable sand substrate; and the lack of pools and cover. Seventy percent of the substrate at BSS01, BSS04, and BSS08 is sand; and hardpan clay makes up an increasing proportion of the substrate in downstream progression, because of the scouring that occurs from unnaturally high velocities. Overall, the data shows that Salt Creek is a wide, shallow, open sandy run with limited habitat at all these stations.

7.1.2 Chemical Data

Samples were collected for total ammonia and chloride analyses at stations BSS01, BSS04, and BSS08 during each bio-assessment, along with *in situ* water quality parameters. Seventeen sets of chemical samples and *in situ* water quality parameters were also collected at these stations during separate chemical sampling events. Like the hydraulics and habitat data, water chemistry provides information about the similarity of the living conditions for aquatic organisms among sites. In addition, the pH and temperature data document the range of exposure conditions that may have affected the relative proportions of ionized and un-ionized ammonia in Salt Creek.

Comparisons of summer pH, temperature, and dissolved oxygen show similar conditions among the stations (Figure 7-2). Median temperatures were in the range of 21 – 24 ^{o}C, with a trend of slightly increasing temperatures in a downstream progression. Median dissolved oxygen (DO) concentrations were 7.8 – 8.1 mg/L at all stations. Median pH was approximately 8.1 S.U. at all sites. Median conductivity values (5,425 to 5,685 mhos/cm) and chloride concentrations (1,500 – 1,700 mg/L) were also similar at stations BSS01, BSS04, and BSS08. For comparison, Bazata et al. (1991) reported that the median conductivity in streams located in the Western Corn Belt Plains of Eastern Nebraska is 610 μmhos/cm.

The evaluation of the median condition for stream hydraulics, habitat quality, and conventional water chemistry shows similar living conditions for fish and benthic macroinvertebrates at stations BSS01, BSS04, and BSS08. However, there was variability in pH and temperature over time indicating that the aquatic community in Salt Creek was exposed to a range of pH and temperature combinations that affected the relative proportions of ionized and un-ionized ammonia. For example, temperatures at station BSS08 ranged from 15 – 32 °C during the summer and pH ranged from 7.4 – 8.5 S.U.

The variable that <u>does</u> change between the reference stations and impact stations is total ammonia. The effect of total ammonia on the biota is discussed below.

7.3 Relative Difference Calculations

The Relative Difference (RD) was calculated for each metric between Stations BSS01 and BSS04, and Stations BSS01 and BSS08, separately. These calculations were also completed for each summer bio-assessment event. The RD only exceeded the 0.15 threshold for the number of chironomid taxa at BSS04 during August 1995 and at BSS08 during September 1996 (Table 7-1). The RD did not exceed 0.15 for the number of macroinvertebrate taxa during any of the summer bio-assessments. The RD values calculated with the macroinvertebrate data only indicated ammonia impairment in two of 24 comparisons between the control site and impact site data.

The RD for the number of fish species exceeded 0.15 at BSS04 during 3 of 6 bio-assessments, and it exceeded 0.15 at station BSS08 during five events. The RD for the number of cyprinids exceeded 0.15 during two bio-assessments at BSS04 and during four events at station BSS08. The prior 180-day maximum 30-day concentrations preceding the events with such RD exceedances ranged from 1.29 to 5.53 mg N/L total ammonia.

7.4 Linear Regression of Relative Difference and Fish Richness

No linear regression is warranted for the macroinvertebrate data because the RD values only indicate impact in two of 24 comparisons. A number of regressions were completed with the fish metrics to evaluate their relationship to ammonia toxicity. The issues of concern included:

- The total ammonia exposure period that was best associated with the decline in taxa richness. It was assumed that the maximum 30-day average ammonia concentration preceding the bio-assessment was an appropriate selection, because the response of biological communities reflect long-term chemical exposure. However, evaluating the relationship of the RDs to the 30, 60, 90 and 180-day exposure periods preceding each bio-assessment tested this assumption (Table 7-2).

- The similarity of the response to ammonia toxicity for the number of fish species and the number of native cyprinids. These metrics may reflect differing sensitivity to ammonia toxicity, and the pseudoreplicate sampling showed that the cyprinids metric was more variable.

- The effect of the effluent quality discharged from each WWTP, since the plants receive wastewater from different sources, and more industrial sources discharge to the Theresa Street WWTP.

- The pattern of responses over the six-year period.

The coefficient of determinations (R^2) for the regressions of the RD values for the fish metrics to ammonia (maximum and 95th percentile; daily and 30-day average) for 30, 60, 90, and 180-day periods prior to the bio-assessments are presented in Table 7-2. The R^2 values for the combined metrics and the 30, 60 and 90-day exposure periods range from 0.0029 – 0.0586 at BSS08. The R^2 values for the combined metrics and the 180-day exposure period ranged from 0.65 to 0.75.

The differences in the correlations at Station BSS08 among the exposure periods have a reasonable explanation. Figure 7-3A and Figure 7-3B show the simulated distribution of ammonia concentrations in Salt Creek at Station BSS08 for each year, 1994 – 1999. The vertical bars on the figures identify the dates of the winter and summer bio-assessments. The bio-assessments were conducted in February or March and in August or September so the events were separated by about 180 days. The plots also show that the highest ammonia concentrations occur in March and April, after the winter bio-assessments and before the summer event. In addition, Table 7-3 shows the spawning period for 33 of the fish species collected from Salt Creek. Spawning times are for Nebraska or surrounding states with similar latitudes. The spawning data shows that spawning begins in March and most of the activity occurs in April, May, and June. Taken together, the distribution of ammonia concentrations and timing for spawning show that the high correlations between ammonia impacts and the 180-day exposure period are empirically justified, because the highest ammonia concentrations occur approximately 180 days before the summer bio-assessments, and these high concentrations coincide with spawning activity and exposure to sensitive early life stages (USEPA, 1999). These seasonal elevations in ambient ammonia are the result of high effluent ammonia caused by reduced nitrification in the WWTP's during winter and spring.

It is also important to note the high correlations with the daily maximum values. These results may indicate that short exposures of high concentrations of ammonia to sensitive life stages may cause a significant impact to the instream community, while longer exposures of lower concentrations to less sensitive life stages have limited impacts on community structure. This hypothesis is consistent with the nature of ammonia as a fast acting, non–bioaccumulating toxicant. The implication of these results is that the timing for ammonia exposures is as important as the magnitude of the concentration.

The regressions of the RDs for the combined metrics and the prior 180-day maximum 30-day average total ammonia has a R^2 of 0.65 for station BSS08, and the regression line intercepts the RD = 0.15 line at 2.25 mg N/L total ammonia (Figure 7-4). When the RDs for the two metrics are correlated separately with maximum total ammonia concentrations at BSS08, the R^2 values (0.69 and 0.71) and the points of intersection of the RD = 0.15 lines (2.02 and 2.38 mg N/L) are similar.

At station BSS04, the regressions of the RDs for the combined metrics and the 180-day maximum 30-day average total ammonia have a R^2 value of 0.14 (Figure 7-5). The R^2 for each metric are also equivalent to the combined R^2 value (0.14). Review of the Figure 7-5 shows the presence of two data points from August 1998 that may be outliers. These two data points have negative RD values, which indicate more species of fish were present at the potentially impacted station than at the control station. Review of field notes made during the bio-assessment shows that ambient water temperatures were different at the two stations. At the time of the collection, water temperature was 31.7 ºC (89.6 ºF) at BSS01 and 26.7 ºC (80 ºF) at BSS04. The difference in ambient water temperature at the two stations was caused by the cooler wastewater discharge from the Theresa Street WWTP 24.3 ºC (75.7 ºF). The lower water temperatures observed at

BSS04 probably created refugia for fish that resulted in more species of fish collected at BSS04.

Removal of the August 1998 RD values from the regression analysis results in R^2 values that are very similar to those observed for BSS08 (Table 7-4). The regression of the RDs for the combined metrics and prior 180-day maximum 30-day average total ammonia have a coefficient of determination value of 0.86 for station BSS04, and the regression line intercepts the RD = 0.15 line at 2.12 mg N/L total ammonia (Figure 7-6). When the RDs for the two metrics are correlated separately with maximum total ammonia concentrations at BSS04, the coefficient of determination values (R2 = 0.83 and 0.95) and the points of intersection of the RD = 0.15 lines (2.32 and 1.98 mg N/L) are similar.

The similarity of the biological response to ammonia from the Theresa St. (less August 1998 data) and Northeast WWTP indicates that the sensitivities of: (1) all fish species, and (2) cyprinid species in Segment LP2-20000 are similar for ammonia toxicity (Figure 7-4 and Figure 7-6). The high coefficient of determination suggests that the decline in taxa richness downstream from the Theresa St. and Northeast WWTP's is largely attributable to ammonia toxicity.

7.5 Winter Biological Conditions in Salt Creek

This report has primarily focused on the summer biological communities in Salt Creek and the effects of ammonia on this community. Several aspects have guided this analysis and are as follows:

- Efforts were focused on the development of summer criteria because it is the time of greatest impact for ammonia toxicity. The toxic fraction of ammonia is greater and fish are more sensitive to ammonia during warm water periods (U.S.EPA, 1999).

- The impacts of ammonia on the biological community during the winter were evaluated, and no correlation was found between fish and benthic macroinvertebrate metrics and ambient ammonia. The toxic fraction of ammonia is less, and fish are less sensitive to ammonia during coldwater periods. (U.S EPA, 1999).

- The fish metrics are less sensitive to ammonia during the winter, because there are fewer species present due to poor over-wintering habitat for many species in Salt Creek, primarily due to channelization.

- The 1999 EPA ammonia document (U.S. EPA, 1999) provides for the implementation of site specific winter ammonia criteria (chronic criterion or CCC) based on the absence or presence of fish Early Life Stages (ELS) during the winter season).

- Derivation of a winter ELS absent CCC is based on a site-specific summer CCC.

7.5.1 Winter Season Early Life Stage Absent Documentation

The 1999 EPA Ammonia document (U.S. EPA, 1999) provides for the implementation of site specific ammonia criteria (chronic criterion or CCC) based on the absence or presence of fish Early Life Stages (ELS) during the winter season. The provision allows for the relaxation of the ammonia CCC when ELS of fish are not present. At low ambient water temperatures, adult and juvenile fish are less sensitive to ammonia toxicity than are the ELS. General guidance for implementation and documentation of an ELS absent site-specific chronic criteria is provided in the public notice "Water Quality Criteria; Notice of Availability; 1999 Update of Ambient Water Quality Criteria for Ammonia" (U.S. EPA, 1999). This document defines the ELS period as being the time from egg laying until a fish is anatomically similar to adults (juvenile).

Maret and Peters (1978) and the City of Lincoln (1994-1999) using scientifically valid sampling procedures have documented the species of fish inhabiting Salt Creek (Segment LP2-20000). Maret and Peters' work was performed to fulfill the requirements of a master's thesis and included sampling during the spring, summer and fall. The City of Lincoln's work represents six fish surveys conducted each summer (August-September) from 1994 to 1999 as part of the Salt Creek Water Quality Studies. The species of fish collected during these two studies are presented in Table 7-3.

A review of the list shows that no Federal or State threatened or endangered fish have been collected from Salt Creek. Also absent from any collections are Salmonidaes (salmon and trout) which are known late fall to winter spawners. Maret's work encompassed the entire Salt Creek drainage basin, and no threatened or endangered fish were collected in the basin either. This list represents the fish, which may potentially spawn in Salt Creek; however, this does not imply that they do spawn within Segment LP2-20000 of Salt Creek. Review of the spawning time periods of the fish collected from Salt Creek shows that the earliest spawner would be the gizzard shad (*Dorosoma cepedianum*) in early April and the creek chub (*Semotilus atromaculatus*) in late March. The latest spawning fish collected from Salt Creek is the red shiner (*Cyprinella lutrensis*), which may spawn as late as early September (Missouri). A review of the early life stage history of the red shiner, as presented by Sakensa (1962) using laboratory raised specimens, shows that the ELS period for the red shiner is 34 days. This number does not include the egg incubation period, which was given as 72 hrs (3 days). Thus, the ELS period for red shiners, the latest spawning fish applicable to Salt Creek, is 37 days.

Based on the data presented, the estimated time period for the absence of ELS of fish from Salt Creek would encompass the time period from approximately October 20 (September 10 + 37 days for the red shiner ELS period) until March 20.
This time period (October 20 – March 20) for ELS absent from Salt Creek, as documented by scientifically sound collections from Salt Creek Segment LP2-20000, corroborates the proposed ELS absent regulatory time period (1 November – February 28) proposed by NDEQ for inclusion in Title 117 (NDEQ, 2000).

8.0 DISCUSSION AND RECOMMENDATIONS

The City of Lincoln and their team of consultants (Brown and Caldwell, EA Engineering, and CH2M Hill) used bio-assessment results to derive site-specific ammonia criteria for Segment LP2-20000. This approach to criteria derivation was selected, because it is empirical, ecologically relevant, based on long-term monitoring data, and corroborated by independent evidence.

The taxa richness biometrics selected for Salt Creek are reliable indicators of pollution stress to aquatic organisms, and their response was demonstrated with data from streams in eastern Nebraska. The metrics incorporate the response of a large number of taxa: 17 fish species, 7 native cyprinid species, 135 macroinvertebrate genera, and 21 chironomid genera. Native cyprinids are the dominant family of fish in Salt Creek, and they comprise 55% – 65% of the individuals collected from the stream during the summer. Chironomids also often account for more than 50% of the macroinvertebrate abundance in the Creek during the summer.

The regressions for the fish metrics and ammonia demonstrate a long-term, chronic dose-response relationship for the fish community. The high correlations between the reductions in taxa richness for the 180-day exposure period to ammonia demonstrate the annual, repeatable change in fish community structure in response to elevated ammonia concentrations during spawning periods. The strength of these correlations is based on a consistent pattern in this response over a six-year period. The response of the fish to ammonia is similar for all fish species and native cyprinid species, and for the ammonia discharges from both plants. The maximum safe ammonia concentration predicted with the BSS04 data was 2.12 mg/L and the safe concentration predicted with the BSS08 data was 2.25 mg/L.

The decline in the number of fish taxa in response to total ammonia is corroborated by independent evidence. Fish are generally more sensitive to ammonia than benthic macroinvertebrates. The genus mean acute values (GMAV) and their rank with respect to ammonia sensitivity are provided for 35 freshwater species in the 1999 "Update of Ambient Water Quality Criteria for Ammonia" (USEPA, 1999). Fish genera are 9 of the 10 most sensitive genera, including the *Lepomis sp*. (rank 5) and *Notropis sp*. (rank 7) that were collected from Salt Creek. The higher tolerance of macroinvertebrates to ammonia explains why only two of 24 RD values exceeded 0.15 at the stations downstream from the WWTP's.

The relationship between the RD values for the number of fish species and Cyprinid species and total ammonia at stations BSS04 and BSS08 is an accurate measurement of long-term ammonia impacts in Salt Creek. These relationships can be used to identify a site-specific chronic criteria for ammonia, because the criteria is derived in the context of all the other stressors to the biota over a six-year period (Salt Creek bio-assessment study period). There is no need to adjust or correct the criteria value for critical, stressful environmental conditions because the ammonia exposures occurred in combination with the actual living conditions for the fish and over a range of pH and temperature conditions that affect ammonia toxicity.

Other investigators have shown that biometrics with RD ≤0.15 demonstrate no impairment to the biota collected downstream from wastewater discharges. This threshold of impact is similar to the 20% Effect Concentration used by USEPA as the threshold for chronic toxicity. Based on the strong RD and total ammonia correlations for Stations BSS04 and BSS08, it is concluded that 2.1 mg N/L total ammonia is a protective site-specific criteria for Segment LP2-20000 of Salt Creek. This value is the highest 30-day average concentration that will protect sensitive life stages from long-term exposures.

It is recommended that 2.1 mg N/L be used in a weight-of-evidence approach with the EC20 value derived from the *in situ* testing conducted in Salt Creek (see Manuscript 2) to derive the final site-specific criteria for total ammonia in Segment LP2-20000. Specifically, it is recommended that the ammonia criteria derived from bio-assessment be used as the lower bound or "floor" for the criteria calculation; meaning that the final criteria should not be less than the 2.1 mg N/L value which has been shown to be protective to the indigenous community.

Electronic Version: **Go to Manuscript 2 – Salt Creek *in situ* Toxicity Testing Program (next manuscript)**

Return to Start of Report (for Table of Contents)

Links to Supporting Data Files

REFERENCES

American Petroleum Institute. 1981. The Sources, Chemistery, Fate, and Effects of Ammonia in Aquatic Environments. American Petroleum Institute. Washington D.C.

Barbour and Stribling. In review. Barbour, M.T. and J.B. Stribling, 1991. Use of Habitat Assessment in Evaluation the Biological Integrity of Stream communities. In Press.

Barbour, M.T., and J.B. Stribling. 1994. A technique for assessing stream habitat structure. In Proc. Of Riparian Ecosystems. 156-178. Washington, D.C: National Association of Conservation Districts.

Barbour, M.T., *et al*. 1996. Development of the Stream Condition index (SCI) for Florida, Florida Department of Environmental Protection, Tallahassee, Florida.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling, 1999. Rapid Bio-assessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington D.C.

Bazata, Ken. Personal Conversations. April 1994.

Bazata, Ken. Personal Conversations. February, March, May 1999.

Bliss, Q.P. and S. Shainost. 1973. Lower Platte Basin Stream Inventory Report. Lincoln, Nebraska Game and Parks Commission

Burton, G.A. Jr., C.W. Hickey, T.H. DeWitt, D.S. Roper, D.J Morrisey and M.G. Nipper. 1996. *In Situ* Toxicity Testing: Teasing Out the Environmental Stressors. *SETAC News*. 16(5):20-21.

City of Lincoln, Nebraska. 1994. Salt Creek Water Quality and Effluent Management Studies Workplan.

City of Lincoln, Nebraska. 1996. Salt Creek Water Quality Studies Report.

DeShon, J.E. 1995. Development and Application of the Invertebrate Community Index (ICI). Pages 217-244 In W.S. Davis and T.P. Simon, eds. Biological Assessment and Criteria : Tools for Water Resource Planning and Decision Making. Lewis, Boca Raton, FL.

Diamond, J., *et al*. 1999. Evaluating Whole Effluent Toxicity Testing as an Indicator of Instream Biological Condition, Water Environmental Research Foundation., 601 Wythe Street, Alexandra, Virginia, 22314-1994.

Dickson, K., W. Waller, J. Kennedy, and L. Ammann .1992. Assessing the Relationship Between Ambient Toxicity and Instream Biological Response. Environ. Toxicol. Chem. 11: 1307-1322.

Donley, S.R., 1991. Development of Biological Criteria for macroinvertebrates for Streams of the Western Corn Belt Plains Ecoregion., submitted to the Graduate School of the University of Kansas in partial Fulfillment of the Requirements for the Degree of Master of Arts.

Fore, L.S., J.R. Karr, and R.W. Wissman. 1996. Assessing Invertebrate Responses to Human Activities: Evaluating Alternative Approaches. J.N. Am. Benthol. Soc. 15: 212-231.

Frenzel, S. A., and S. B. Swanson. 1996. Relations of Fish Community Composoition to Environmental Variables in Streams of Central Nebraska, USA. US Geological Survey, 4821 Quali Crest Place, Lawrence, Kansas 66049.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream Hydrology: An Introduction for Ecologists. Centre for Environmental Applied Hydrology. University of Melbourne. John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex. PO19 1UD, England.

Groeth, D.R., K.L. Dickson, D.K. Reed-Judkins (editors). Methods and appropriate, endpoints in *Whole Effluent Toxicity Testing: An Evaluation of Methods and Prediction of Receiving System Impacts*. SETAC Press, Pensacola, Florida.

Karr, J.R. 1981. Assessment of Biotic Integrity Using Fish Communities, Fisheries. 6:21-27.

Karr, J. R., and E. W. Chu. 1999. Restoring Life in Running Water/ Better Biological Monitoring, Island Press, 1718 Connecticut Avenue, Washington, D.C. 20009.

Kerans, B.L. and J.R. Karr. 1994. A Benthic Index of Biotic Integrity (B-IBI) for Rivers of the Tennessee Valley. Ecol. Appli. 4: 768-785.

Koizumi, N., and Y. Matsumiya. 1997. Assessment of Stream Fish Habitat Based on Index of Biotic Integrity. Bull. Jpn. Soc. Fish Oceangr. 61: 144-156.

Lyons J., S. Navarro-Perez, P.A. Cochran, E. Santana C., and M. Guzman-Arroyo. 1995. Index of biotic integrity based on fish assemblages for the conservation of streams and rivers in west-central Mexico. Conserv. Biol. 9:569-584.

Lyons, J., L. Wang., and T.D. Simonson. 1996. Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin., N. Am. J. Fish Manag. 16: 241-256.

Miller, D.L. and 13 others. 1998. Regional Applications of an Index of Biotic Integrity For Use in Water Resource Management. Fisheries 13(5): 12-20.

Mount, D. 1994. A Comparison of Strengths and Limitations of Chemical Specific Criteria, Whole Effluent Toxicity Testing and Biosurveys. AscI Corporations/AscI Duluth, Duluth Minnesota.

Nebraska Stream Classification Study. 1991. Surface Water Section, Water Quality Division, Nebraska Department of Environmental Control, Ken Bazata, Report Coordinator. P.O. Box 98922, 301 Centennial Mall South, Lincoln, NE 68509-8922.

Nebraska Department of Environmental Quality. 1992. Procedures for Developing Wasteload Alocations.

NDEQ. 2000. Nebraska Department of Environmental Quality, 2000. John, Bender Memorandum. Explanatory and Fiscal Impact Statements for Proposed Revisions to Title 117 - Nebraska Surface Water Quality Standards. April 21, 2000. NDEQ. Lincoln, Nebraska.

Nebraska Surface Water Quality Report. 1994. Water Quality Division, Nebraska Department of Environmental Quality, Michael Callam, Report Coordinator, P.O. Box 98922, 301 Centennial Mall South, Lincoln, Nebraska. 68509-8922.

Nebraska Stream Classification Study. 1995. Draft Metric Revision for Nebraska Stream Classification Study (Draft). Surface Water Section, Water Quality Division, Nebraska Department of Environmental Control, Ken Bazata, Report Coordinator. P.O. Box 98922, 301 Centennial Mall South, Lincoln, NE 68509-8922.

Nebraska Surface Water Quality Report. 1996. Water Quality Division, Nebraska Department of Environmental Quality, Michael Callam, Report Coordinator, P.O. Box 98922, 301 Centennial Mall South, Lincoln, Nebraska. 68509-8922.

Nebraska Surface Water Quality Report. 1998. Water Quality Division, Nebraska Department of Environmental Quality, Michael Callam, Report Coordinator, P.O. Box 98922, 301 Centennial Mall South, Lincoln, Nebraska. 68509-8922.

North Carolina Department of Health and Natural Resources. 1990. Standard operating procedures, biological monitoring. Environmental Science Branch, Ecosystems Analysis Unit, Biological Assessment Group, Water Quality Section, Environmental Management, Raleigh, North Carolina.

Ohio Environmental Protection Agency, 1988. Biological Criteria for the Protection of Aquatic Life, Vol 1-3. Ecological Assessment Section Division of Water Quality Monitoring and Assessment, Ohio Environmental Protection Agency, Columbus.

Ohio Environmental Protection Agency. 1989. Biological Criteria for the protection of aquatic life. In Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities. Vol. III., Columbus: Ohio EPA Division of Water Quality Planning and Assessment, Ecological Assessment Section.

Pflieger, W. L. 1975. The Fishes of Missouri. Missouri Department of Conservation,

Plafkin, *et al*. 1989. Rapid Bio-assessment Protocols for use in Streams and Rivers; Benthic Macroinvertebrates and Fish. EPA/444/4-89-001. U.S. Environmental Protection Agency, Assessment and Watershed Protection Division, 401 M. Street, S.W., Washington, D.C. 20460.

Reynoldson, T.B., and J.L. Metcalfe-Smith. 1992. An Overview of the Assessment of Aquatic Ecosystem Health Using Benthic Invertebrates. J. Aquati. Ecosyst. Health 1: 295-308.

Resh, V. H., and J. K. Jackson, (1993) Rapid Assessment Approaches to Biomonitoring Using Benthic macroinvertebrates. In Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York.

Rivera, M., and C. Marrero. 1994. Determinacion de la calidad de las aquas en las cuencas hidrograficas, mediante la utilization del indice de integridad biotica (IIB). Biollania 11: 127-148.

Rodriquez-Olarte, D., and D.C. Taphorn. 1994. Los peces como indicadores biologicos: Aplicacion del indice de integridad biotica en ambientes acuaticos de los llanos occidentalas de Venezuela. Biollania 11: 27-56.

SCWQS. 1996. Brown and Caldwell, EA Engineering, Science and Technology, Kelly and Weaver, LTI – Limno-Tech., Regulatory Management, Inc., February 16, 1996. Salt Creek Water Quality Studies Report, Vol. 1.

SCWQS. 1997. Brown and Caldwell, EA Engineering, Science and Technology, Kelly and Weaver, July 18, 1997. Addendum 2 to Salt Creek Water Quality Studies Report.

Simon, T.P., and J. Lyons. 1995. Application of the Index of Biotic Integrity to Evaluate Water Resource Integrity in Freshwater Ecosystems. Pages 245-262 in W.S. Davis and T.P. Simon, eds. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis, Boca Raton, FL.

Thorne, R. St., J., and W.P. Williams. 1997. The Response of Benthic Invertebrates to Pollution in Developing Countries: A Multimetric System of Bio-assessment. Freshwater Biol. 37: 671-686.

U.S. Environmental Protection Agency. 1994. Guidance for the Data Quality Objectives Process. EPA QA/G-4. Quality Assurance Management Staff, Washington, D.C. 20460.

U.S. Environmental Protection Agency. 1996. Biological Criteria: Technical Guidance for Streams and Small Rivers, Revised Ed. EPA 822-B-94-001. U.S. Environmental Protection Agency, Office of Science and Technology. Washington, D.C. May 1996

U.S. Environmental Protection Agency, 1999. Second Edition Rapid Bio-assessment Protocols, Washington, D.C. 20460.

U.S. Environmental Protection Agency, 1999. 1999 Update of Ambient Water Quality Criteria for Ammonia. Office of Water, Washington D.C.

Yoder, C.O. 1995. Policy issues and management spplications for biological criteria, in *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*, (Davis, W.S., Simon, T.P., eds), pp.327-343. Lewis Publishers, Boca Raton, Florida

Table 6-1 Fish Collected from the Western Corn Belt Plains Ecoregion and Salt Creek

Western Corn Belt Plains, Summer, NDEQ				Salt Creek, Summer, City of Lincoln		
Species	**Count**	**Percent**		**Species**	**Count**	**Percent**
Sand shiner	4797	33.6		red shiner	1930	36.2
Fathead minnow	2493	17.5		sand shiner	671	12.6
Red shiner	2476	17.4		plains minnow	514	9.6
Creek chub	1195	8.4		green sunfish	468	8.8
Green sunfish	564	4.0		common carp	445	8.3
Bigmouth shiner	501	3.5		channel catfish	248	4.7
Central stoneroller	334	2.3		river carpsucker	234	4.4
Brassy minnow	288	2.0		fathead minnow	201	3.8
Channel catfish	246	1.7		gizzard shad	185	3.5
River carpsucker	241	1.7		emerald shiner	126	2.4
Black bullhead	220	1.5		bluegill	94	1.8
Suckermouth minnow	166	1.2		freshwater drum	41	0.8
Gizzard shad	147	1.0		shortnose gar	35	0.7
Carp	100	0.7		quillback	30	0.6
Flathead chub	86	0.6		largemouth bass	16	0.3
Yellow bullhead	82	0.6		suckermouth minnow	16	0.3
Plains minnow	53	0.4		white crappie	16	0.3
Stonecat	43	0.3		flathead catfish	14	0.3
Quillback	42	0.3		black crappie	9	0.2
Emerald shiner	26	0.2		goldeye	7	0.1
Plains topminnow	25	0.2		brook silverside	6	0.1
White sucker	18	0.1		stone cat	6	0.1
Orange-spotted sunfish	18	0.1		yellow bullhead	6	0.1
Bluegill	15	0.1		river shiner	4	0.1
Largemouth bass	13	0.1		silver chub	2	0.0
Blacknose dace	12	0.1		speckled chub	2	0.0
Shortnose gar	9	0.1		walleye	2	0.0
Plains killfish	7	0.0		big mouth shiner	1	0.0
Orangethroat darter	6	0.0		bighead carp	1	0.0
Western silvery minnow	5	0.0		gambusia	1	0.0
Brook stickleback	3	0.0		goldfish	1	0.0
White bass	3	0.0		western silvery minnow	1	0.0
River shiner	3	0.0		Shorthead Redhorse	1	0.0
Bluntnose minnow	3	0.0				
White crappie	3	0.0		**Total Fish**	**5,333**	
Freshwater drum	2	0.0				
Speckled chub	2	0.0		**Total Species**	**33**	
Black crappie	2	0.0		**Total Cyprinids**	**11**	
flathead catfish	2	0.0		**Sampling Events(N)**	**6**	

Western Corn Belt Plains, Summer, NDEQ				Salt Creek, Summer, City of Lincoln		
Species	Count	Percent		Species	Count	Percent
walleye	2	0.0				
Johnny darter	1	0.0				
goldeye	1	0.0				
bigmouth buffalo	1	0.0				
shorthead redhorse	1	0.0				
notropis	1	0.0				
				Bold - Indicates common species		
Total Fish	**14,258**			**Shaded - Indicates Native Cyprinids**		
Total Species	**45**					
Total Cyprinids	**16**					
Sampling Events(N)	**76**					

Table 6-2 Summary of Conditions in Eastern Nebraska Streams Used to Select Biometrics for Salt Creek

Stream Type	Stream Name	Biological Site ID	Stream Segment	Sample Date	Attainment	Use Class	Assessment	Impairment/source	Drainage Area, Ac.	Flow Class	Temp °C	D.O. mg/L	Cond. µmhos/cm	Fish Taxa	Native Cyprinids	Insect Taxa	EPT	Chiro Taxa
Streams classified as reference sites based on habitat condition as well as IBI and ICI scores (NDEQ, 1995).																		
E/W/2/N/A	Turkey Creek	BB2035	BB2-10000	Jul-85	F	A	Mb	None Given	4965	5	24.5	9.4	700	10	3	33	10	13
E/W/2/N/A	Turkey Creek	BB2035	BB2-10000	Aug-91	F	A	Mb	None Given	4965	3	29	ND	700	9	3	33	10	13
E/W/2/S/A	Spring Creek	BB1003	BB1-10300	Jul-85	F	A	Ec	B/2	71.62	2	23	11.5	650	11	6	22	7	0
E/W/2/N/I	Rattlesnake Cr.	NE2047	NE2-11980	Jul-86	F	A	Mb	B/4	92.3	2	25	9.2	750	8	5	52	10	17
E/W/2/N/I	Rattlesnake Cr.	NE2047	NE2-11980	Jul-90	F	A	Mb	B/4	92.3	2	19	11.1	750	12	5	52	10	17
E/W/2/N/I	Rattlesnake Cr.	NE2047	NE2-11980	Jun-92	F	A	Mb	B/4	92.3	2	28	6.8	1010	11	7	52	10	17
E/W/1/N/A	Lores Br.	NE2053	NE2-12110	Jul-86	F	A	Mb	None given	100.49	2	25	8.2	420	11	3	61	12	12
E/W/1/N/A	Lores Br.	NE2053	NE2-12110	Jul-90	F	A	Mb	None Given	100.49	2	21	9.9	450	13	6	61	12	12
E/W/1/N/A	Lores Br.	NE2053	NE2-12110	Aug-90	F	A	Mb	None Given	100.49	2	22	6.4	465	11	6	61	12	12
E/W/1/N/A	Lores Br.	NE2053	NE2-12110	Jul-92	F	A	Mb	None Given	100.49	2	31	9	590	10	7	61	12	12
E/W/1/E/A	Cottonwood Cr.	RE1008	REI-10400	Jun-88	F	A	Mb	B,H/2,8	101.1	1	31	5.9	700	7	4	29	5	8
E/W/1/E/A	Cottonwood Cr.	RE1008	REI-10400	Aug-91	F	A	Mb	B,H/2,8	101.1	1	28	ND	ND	7	4	29	5	8
E/W/3/N/A	S.E. Big Nemaha	NE2045	NE2-11900	Jul-90	F	A	Ea,Mbe	B/2	4504	6	33.9	7.6	650	10	5	44	11	16
E/W/3/N/A	S.E. Big Nemaha	NE2045	NE2-11900	Jul-92	F	A	Ea, Mbe	B/2	4504	6	27	9.2	670	10	5	44	11	16
E/W/3/N/A	S.E. Big Nemaha	NE2045	NE2-11900	Jun-94	F	A	Ea,Mbe	B/2	4504	6	33.9	7.6	65	9	3	ND	ND	ND
Stream type similar to Salt Creek but is not designated as a reference site.																		
E/W/3/N/A	Elkhorn River	EL1002	EL1-10000	Jul-94	F	A	Eacf,Mf	A/1,2,3; B/2; D/10; C/1	640	9	25	5.9	420	9	6	19	12	4
Channelized streams as defined the 1996 305B report (NDEQ, 1996)																		
W/W/2/N/I	Aowa Cr.	Mt2073	MT2-10500	Jun-90	P	A	Mb	B/2,5	6.1	4	22	14.5	600	7	5	12	1	3
W/W/3/N/A	Logan Creek	EL2008	EL2-20000	Sep-84	N	A	Eef	B/2,5	22.1	7	19	9.2	ND	8	4	20	7	8
W/W/3/N/A	S. Logan Cr.	EL2010	EL2-20800	Oct-84	P	A	Ec	B/5	75.3	1	7	11.9	650	6	6	31	11	11
E/W/2/N/A	Middle Cr.	LP2088	LP2-21100	Jun-93	P	B	Ec	B/5	3	3	21	7.2	770	5	4	ND	2	5
Streams impacated by un-ionized ammonia as defined by NDEQ, 1998 303d list.																		
E/W/3/N/A	Big Blue River	BB100B	BB1-20000	Jul-85	P	A	Eac,Mf	C/6; B/2; A/1,2,3	332	7	22	7.8	470	6	2	18	10	1
E/W/2/S/I	Mud Creek	LO4074	LO4-10200	Aug-88	F	B	Mbf	C/1; B/2	66.6	3	21	ND	ND	2	1	18	6	ND
E/W/3/N/A	Salt Creek	LP2062		94-98	P	A	SCWQS Biological Stations BSS04 and BSS08											

Keys to Abbreviations:

Stream Types: Example = EW3NA
First Letter - E = East or W = West
Second Letter - W = Warmwater
Number – Estimate of base flow. 1 = ,1 cfs, 2 = 1 to 25 cfs, 3 = 25 to >500cfs
Third Letter - N = no vegetation, S = Submergent Vegetation, E = Emergent Vegetation
Fourth Letter – A = Sand/Gravel Substrate, I = Silt/Clay substrate

Attainment F = Full, P = Partial, N = Non-attainment as defined in the 1995 stream classification document
Use Class A = Warm Water A, B = Warmwater B
Assessment M = Monitored, E = Evaluated; a=Grab samples for fecal coliform, b= Combined Biological Index samples collected last 5 years, c=Combined Biological Index samples greater than 5 years old,
e=Assessment based on analytical results of fish tissue analysis, f=Assessment based on water quality samples, g=best professional judgement
Impairment/Source A=Pathogens, B=Biodiversity Impacts, C=Unionized Ammonia, D=Pesticides, H=Siltation.
1=Municipal Pt. Source, 2=Agriculture NPS, 3=Natural, 4=Unknown, 5=channelized, 6=Industrial Pt. Source, 8=Removal of Riparian Habitat
Flow Class Estimate of stream Base Flow; 1 = <1cfs, 2 = 1-5 cfs, 3 = 5-10 cfs, 4 = 10-25 cfs, 5 = 25-50 cfs, 6 = 50-100 cfs, 7 = 100-250 cfs, 8 = 250-500 cfs, 9 = >500 cfs,
Shaded areas indicate questionable repetitious data.

Table 6-3 Summary of Daily and 30-Day Average Total Ammonia Values

	BSS04						BSS08					
30-days Prior	Daily			30-day			Daily			30-day		
Bio-Assessment Date	Max	95%	Count	Max	95%	Count	Max	95%	Count	Max	95%	Count
08/29/1994	1.58	1.43	30	0.49	0.49	1	1.76	1.56	30	0.74	0.74	1
02/20/1995	3.59	2.83	30	1.71	1.71	1	4.11	3.31	30	2.3	2.30	1
08/21/1995	2.51	1.64	30	0.54	0.54	1	2.67	2.45	30	1.54	1.54	1
03/04/1996	5.60	5.20	30	3.06	3.06	1	6.49	5.90	30	3.95	3.95	1
09/13/1996	3.50	3.37	30	1.6	1.60	1	2.55	2.47	30	1.14	1.14	1
03/05/1997	2.45	2.15	30	1.25	1.25	1	4.56	3.61	30	2.07	2.07	1
08/29/1997	3.22	2.84	30	1.26	1.26	1	3.84	2.93	30	2.08	2.08	1
02/16/1998	4.15	3.56	30	2.04	2.04	1	5.19	4.68	30	2.76	2.76	1
08/17/1998	1.87	1.84	30	1.11	1.11	1	1.28	1.24	30	0.8	0.80	1
02/01/1999	4.45	4.35	30	3.06	3.06	1	4.53	4.40	30	3.24	3.24	1
08/25/1999	4.16	3.36	30	2.31	2.31	1	2.52	1.95	30	1.39	1.39	1

60-days Prior	Daily			30-day			Daily			30-day		
Bio-Assessment Date	Max	95%	Count	Max	95%	Count	Max	95%	Count	Max	95%	Count
08/29/1994	1.58	0.83	60	0.49	0.47	30	1.76	1.00	60	0.74	0.73	30
02/20/1995	3.59	2.53	60	1.74	1.73	30	4.11	3.18	60	2.46	2.44	30
08/21/1995	2.51	1.28	60	0.54	0.54	30	2.67	2.25	60	1.54	1.52	30
03/04/1996	6.38	5.61	60	3.44	3.38	30	7.39	6.78	60	4.55	4.50	30
09/13/1996	3.50	3.24	60	1.6	1.58	30	2.55	2.32	60	1.14	1.11	30
03/05/1997	3.34	2.55	60	1.84	1.84	30	4.56	3.86	60	2.99	2.97	30
08/29/1997	3.22	2.17	60	1.26	1.18	30	3.84	2.78	60	2.08	2.02	30
02/16/1998	4.15	3.82	60	2.5	2.47	30	5.19	4.95	60	3.61	3.57	30
08/17/1998	2.66	1.82	60	1.22	1.21	30	1.67	1.23	60	0.87	0.86	30
02/01/1999	4.83	4.53	60	3.06	3.05	30	4.53	4.46	60	3.24	3.23	30
08/25/1999	4.16	3.10	60	2.31	2.18	30	2.52	1.75	60	1.39	1.31	30

	BSS04						BSS08					
90-days Prior	Daily			30-day			Daily			30-day		
Bio-Assessment Date	Max	95%	Count	Max	95%	Count	Max	95%	Count	Max	95%	Count
08/29/1994	1.58	0.80	90	0.49	0.47	60	1.76	1.23	90	0.74	0.73	60
02/20/1995	3.59	2.65	90	1.92	1.87	60	4.11	3.33	90	2.65	2.60	60
08/21/1995	2.51	1.21	90	0.54	0.54	60	2.67	2.04	90	1.54	1.50	60
03/04/1996	6.38	5.32	90	3.44	3.36	60	7.51	7.14	90	4.55	4.49	60
09/13/1996	3.50	3.06	90	1.6	1.55	60	2.55	2.13	90	1.14	1.08	60
03/05/1997	3.34	2.60	90	1.84	1.83	60	4.56	3.77	90	2.99	2.94	60
08/29/1997	3.22	2.10	90	1.26	1.04	60	3.84	2.56	90	2.08	1.92	60
02/16/1998	5.12	4.31	90	2.83	2.64	60	7.97	5.06	90	3.61	3.53	60
08/17/1998	2.66	1.86	90	1.22	1.20	60	2.73	1.65	90	0.99	0.88	60
02/01/1999	4.85	4.49	90	3.43	3.38	60	4.6	4.44	90	3.24	3.20	60
08/25/1999	4.16	2.82	90	2.31	2.16	60	2.52	1.71	90	1.39	1.30	60

180-days Prior	Daily			30-day			Daily			30-day		
Bio-Assessment Date	Max	95%	Count	Max	95%	Count	Max	95%	Count	Max	95%	Count
08/29/1994	2.21	1.52	180	1.29	1.22	150	2.87	2.14	180	1.84	1.77	150
02/20/1995	4.89	2.85	180	2.1	2.05	150	5.32	3.62	180	2.89	2.81	150
08/21/1995	3.86	2.18	180	1.65	1.40	150	3.81	2.78	180	2.28	2.02	150
03/04/1996	6.67	5.22	180	3.76	3.58	150	10.04	7.05	180	5.64	5.20	150
09/13/1996	7.55	5.79	180	4.74	4.30	150	11.14	6.12	180	5.53	4.96	150
03/05/1997	6.47	3.98	180	3.47	3.38	150	4.96	3.87	180	2.99	2.91	150
08/29/1997	3.22	1.99	180	1.26	1.24	150	3.84	2.77	180	2.14	2.07	150
02/16/1998	10.51	6.64	180	4.86	4.65	150	10.18	6.78	180	5.4	4.90	150
08/17/1998	5.17	3.86	180	3.42	2.87	150	5.83	4.57	180	4.06	3.45	150
02/01/1999	7.83	4.70	180	3.43	3.32	150	5.93	4.46	180	3.24	3.15	150
08/25/1999	5.39	3.48	180	2.92	2.78	150	5.45	3.59	180	3.23	3.09	150

Table 7-1 Summer Metric Value Relative Differences and Prior 180-Day Maximum 30-day average Ammonia Values, Salt Creek (see note)

Date	Metric	Control Station BSS01	Downstream Stations BSS04	BSS08	Relative Difference	Total Ammonia mg/l
Macroinvertebrates						
Sep-94	Taxa No.	21	20		0.024	1.29
	No. Chiro.	9	9		0.000	1.29
	Taxa No.	21		23	-0.045	1.84
	No. Chiro.	9		13	-0.182	1.84
Aug-95	Taxa No.	28	22		0.120	1.65
	No. Chiro.	21	14		**0.200**	**1.65**
	Taxa No.	28		33	-0.082	2.28
	No. Chiro.	21		20	0.024	2.28
Sep-96	Taxa No.	26	27		-0.019	4.74
	No. Chiro.	14	12		0.077	4.74
	Taxa No.	26		33	-0.119	5.53
	No. Chiro.	14		10	**0.167**	**5.53**
Aug-97	Taxa No.	18	21		-0.077	1.26
	No. Chiro.	11	13		-0.083	1.26
	Taxa No.	18		18	0.000	2.14
	No. Chiro.	11		10	0.048	2.14
Aug-98	Taxa No.	32	36		-0.059	3.42
	No. Chiro.	11	15		-0.154	3.42
	Taxa No.	32		27	-0.085	4.06
	No. Chiro.	11		13	-0.083	4.06
Aug-99	Taxa No.	37	34		0.042	2.92
	No. Chiro.	12	10		0.091	2.92
	Taxa No.	37		38	-0.013	3.23
	No. Chiro.	12		15	-0.111	3.23
Aug-99	Taxa No.	20	22		-0.048	2.02
Hester-	No. Chiro.	5	8		-0.231	2.02
Dendy	Taxa No.	20		20	0.000	1.17
	No. Chiro.	5		8	-0.231	1.17
Fish						
Aug-94	Fish No.	15	11		**0.154**	**1.29**
	Cyprinid No.	5	4		0.111	1.29
	Fish No.	15		11	**0.154**	**1.84**
	Cyprinid No.	5		4	0.111	1.84
Aug-95	Fish No.	15	13		0.071	1.65
	Cyprinid No.	6	5		0.091	1.65
	Fish No.	15		13	0.071	2.28
	Cyprinid No.	6		5	0.091	2.28
Sep-96	Fish No.	15	8		**0.304**	**4.74**
	Cyprinid No.	7	3		**0.400**	**4.74**
	Fish No.	15		6	**0.429**	**5.53**
	Cyprinid No.	7		1	**0.750**	**5.53**
Aug-97	Fish No.	10	9		0.053	1.26
	Cyprinid No.	5	4		0.111	1.26
	Fish No.	10		7	**0.176**	**2.14**
	Cyprinid No.	5		3	**0.250**	**2.14**

Date	Metric	Control Station BSS01	Downstream Stations		Relative Difference	Total Ammonia mg/l
			BSS04	BSS08		
Fish (Continued)						
Aug-98	Fish No.	12	14		-0.077	3.42
	Cyprinid No.	3	4		-0.143	3.42
	Fish No.	12		7	**0.263**	**4.06**
	Cyprinid No.	3		2	**0.200**	**4.06**
Aug-99	Fish No.	13	9		**0.182**	**2.92**
	Cyprinid No.	3	2		**0.200**	**2.92**
	Fish No.	13		6	**0.368**	**3.23**
	Cyprinid No.	3		2	**0.200**	**3.23**

Bold Relative Difference values indicate relative values > 0.15 and the observed ammonia value.

Table 7-2 Summary of Fish Summer R Squared Values for Total Ammonia vs. Relative Differences – Salt Creek Water Quality Studies, Lincoln, Nebraska

	BSS08			BSS04		
Exposure Period	Rich + Cyprinid	Richness	Cyprinid	Rich + Cyprinid	Richness	Cyprinid
Prior 30-day						
Maximum Ammonia	R Squared Values					
30-day	0.0081	0.0439	0.0086	0.1522	0.1371	0.1707
Daily	0.0035	0.0118	0.0244	0.3455	0.2779	0.4164
95th Ammonia						
30-day	0.0081	0.0439	0.0008	0.1522	0.1371	0.1707
Daily	0.0309	0.0065	0.1088	0.3855	0.3184	0.4533
Prior 60-day						
Maximum Ammonia						
30-day	0.0092	0.0445	0.0014	0.1177	0.1049	0.1329
Daily	0.0029	0.0115	0.0218	0.1524	0.1067	0.1988
95th Ammonia						
30-day	0.0121	0.0585	0.0019	0.1202	0.1074	0.1355
Daily	0.0586	0.0002	0.1474	0.3062	0.2573	0.3591
Prior 90-day						
Maximum Ammonia						
30-day	0.0112	0.0449	0.0028	0.1177	0.1049	0.1329
Daily	0.0006	0.0065	0.0074	0.1524	0.1067	0.1988
95th Ammonia						
30-day	0.0159	0.0621	0.0043	0.1243	0.1156	0.1364
Daily	0.0558	0.0003	0.1392	0.2611	0.2121	0.3126
Prior 180-day						
Maximum Ammonia						
30-day	0.6531	0.6992	0.7144	0.1392	0.1429	0.1423
Daily	0.7534	0.6888	0.8943	0.2053	0.1849	0.2303
95th Ammonia						
30-day	0.7074	0.7752	0.7637	0.201	0.2057	0.2061
Daily	0.6551	0.6628	0.7388	0.1907	0.1804	0.2068

Prior 180-day						
Maximum Ammonia	Total Ammonia Intercept for RD = 0.15					
30-day	2.25	2.02	2.38	3.24	3.55	3.00
Daily	3.66	3.01	3.97	5.32	5.77	5.05
95th Ammonia						
30-day	2.12	1.94	2.23	2.81	3.04	2.64
Daily	2.69	2.42	2.84	3.80	4.15	3.56

Note = The following species of fish collected from Salt Creek were not included in the Species Richness metric: Gambusia, walleye, bighead carp, goldfish and brook silverside

Table 7-3 Summary of Fish collected from Salt Creek and the4 Potential Spawning Periods

Scientific Name		Maret and Peters, 1978 Common Name	Salt Creek SCWQS, 1994-99 Common Name	Spawning Time Period*	Temperature Requirements (°C)	Hatching Time Period
Lepisosteidae						
	Lepisosteus platostomus	**shortnose gar**	**shortnose gar**	Mid May—July	19.0-23.5	8 days
Clupiedae						
	Dorosoma cepedianum	**gizzard shad**	**gizzard shad**	Early April – June (Iowa)	10.0-21.0	3-4.5 days
Hiodontidae						
	Hiodon alsoides		**gold eye**	Late May--1st week July (Canada)	10.0	12 days
Cyprinidae						
	Cyprinus carpio	**common carp**	**common carp**	Late May/Early April—June	Begins 14-5-17	4-8 days
				May spawn twice	Optimum 18.5-20.0	
	Phenacobius mirabilis		**suckermouth minnow**	Mid April – June	NG	NG
	Semotilus atromaculatus	**creek chub**		Late March (Iowa)	13.0-18.0	6 -10 days
	Hybopsis aestivalis		**speckled chub**	Late July—Late August (Iowa)	NG	NG
	Hybopsis storeriana		**silver chub**	June (Iowa)	Begins 18.0	NG
					Optimum 21.0	
	Notemigonus crysoleucas	**golden shiner**		May—July (Illinois)	20.0-21.0	2-4 days
	Pimephales promelas	**fathead minnow**	**fathead minnow**	Mid May--Early August	15.6-18.4	4.5-6 days
	Hybognathus hankinsoni	**brassy minnow**		June (Iowa)	16.0-27.0	NG
	Hybognathus argyritis	**western silvery minnow**	**western silvery minnow**	Similar to plains minnow		
	Hybognathus placitus	**plains minnow**	**plains minnow**	April – August (Kansas)	NG	NG
	Cyprinella lutrensis	**red shiner**	**red shiner**	Late May -- early September	NG	NG
	Notropis atherinoides	**emerald shiner**	**emerald shiner**	Late May -- early July	24	24 hrs or less
	Notropis ludibundus	**sand shiner**	**sand shiner**	Late June --August (Iowa)	NG	NG
	Notropis blennius	**river shiner**	**river shiner**	Early July -- August (Iowa)	NG	NG
	Notropis dorsalis	**bigmouth shiner**	**bigmouth shiner**	June – August (Iowa)	NG	NG
Catostomidae						
	Carpiodes cyprinus	**quillback**	**quillback**	Early April -- Late May	10.0-20.0	NG
	Carpiodes carpio	**river carpsucker**	**river carpsucker**	Early June -- Late July/Aug (Iowa)	19.0-23.0	NG
				May spawn twice		
Ictaluridae						
	Ictalurus punctatus	**channel catfish**	**channel catfish**	Last wk of May -- 3rd week July	21.1-29.5	6-10 days
	Pylodictis olivaris		**flathead catfish**	Late June – July	23.9-25	6-7 days
	Ictalurus natalis		**yellow bullhead**	May-June (Illinois)	NG	5-10 days
	Ictalurus melas	**black bullhead**		Late June -- Late July (SD)	21	NG
	Noturus flavus		**stone cat**	Early June --Late August (Ohio)	27.8	NG
Cyprinodontidae						
	Fundulus zebrinus	**plains killifish**		July (Wyoming)	NG	NG
Percichtyidae						
	Morone americana	**white perch**		Mid-May -- Late June (Lake Ont.)	11.0-15.0	34-58 hrs
Centrarchidae						
	Micropterus salmoides	**largemouth bass**	**largemouth bass**	Mid April -- late May or June	15.6	31-64 hrs
	Pomoxis nigromaculatus	**black crappie**	**black crappie**	Late June – mid July (SD)	17.8-20.0	48-68 hrs
	Pomoxis annularis	**white crappie**	**white crappie**	May -- June (Iowa and MO)	16.0-20.0	42-93 hrs
	Lepomis cyanellus	**green sunfish**	**green sunfish**	Late June -- August (Iowa)	22.0-26.0	50 hrs
	Lepomis macrochirus	**bluegill**	**bluegill**	late May - - late July/August	22.0-26.0	32-72 hrs
Sciaenidae						
	Aplodinotus grunniens		**freshwater drum**	late April/May	18.0-25.0	22-36 hrs

*Information is from State of Missouri unless otherwise noted.
** NG = (Information) Not
Given

References:

"The Fishes of Missouri", William L. Pflieger, 1975
"Handbook of Freshwater Fishery Biology", Vol I and II, Kenneth D. Carlander, 1969
"Identification of Larval Fishes of the Great Lake Basin with Emphasis On The Lake Michigan Drainage", Nancy A. Auer, 1982
" A Distributional Study of Fishes in Salt Creek Drainage Basin, Nebraska". 1978. Maret and Peters. University of Nebraska Lincoln.
"The Post-hatching Stages of the Red Shiner, Cyprinella lutrensis". 1962. Saksena, V.P. Copeia 1962:539-544

Table 7-4 Summary of Fish R Squared Values for BSS04 Less August 1998 Data Point Total Ammonia vs. Relative Differences Salt Creek Water Quality Studies, Lincoln, Nebraska

	BSS04 Summer		
Exposure Period	Rich + Cyprinid	Richness	Cyprinid
Prior 30-day			
Maximum Ammonia	**R Squared Values**		
30-day	0.2459	0.2074	0.2952
Daily	0.1748	0.1002	0.261
95th Ammonia			
30-day	0.2459	0.2074	0.2952
Daily	0.3648	0.2597	0.4858
Prior 60-day			
Maximum Ammonia			
30-day	0.2459	0.2074	0.2951
Daily	0.1748	0.1002	0.261
95th Ammonia			
30-day	0.2787	0.2368	0.3331
Daily	0.4716	0.3646	0.5982
Prior 90-day			
Maximum Ammonia			
30-day	0.2459	0.2074	0.2951
Daily	0.1748	0.1002	0.261
95th Ammonia			
30-day	0.3286	0.2912	0.3816
Daily	0.4758	0.3601	0.6114
Prior 180-day			
Maximum Ammonia			
30-day	0.8664	0.8269	0.9549
Daily	0.7271	0.6308	0.8565
95th Ammonia			
30-day	0.8708	0.8342	0.9574
Daily	0.8354	0.7555	0.9569
Prior 180-day			
Maximum Ammonia	**Total Ammonia Intercept for RD = 0.15**		
30-day	2.13	2.32	1.98
Daily	4.07	4.37	3.87
95th Ammonia			
30-day	1.97	2.14	1.84
Daily	2.71	2.94	2.54

Note = The following species of fish collected from Salt Creek were not included in the Species Richness metric: Gambusia, walleye, bighead carp, goldfish and brook silverside.

Figure 2-1 SCWQS Biological Sampling Stations

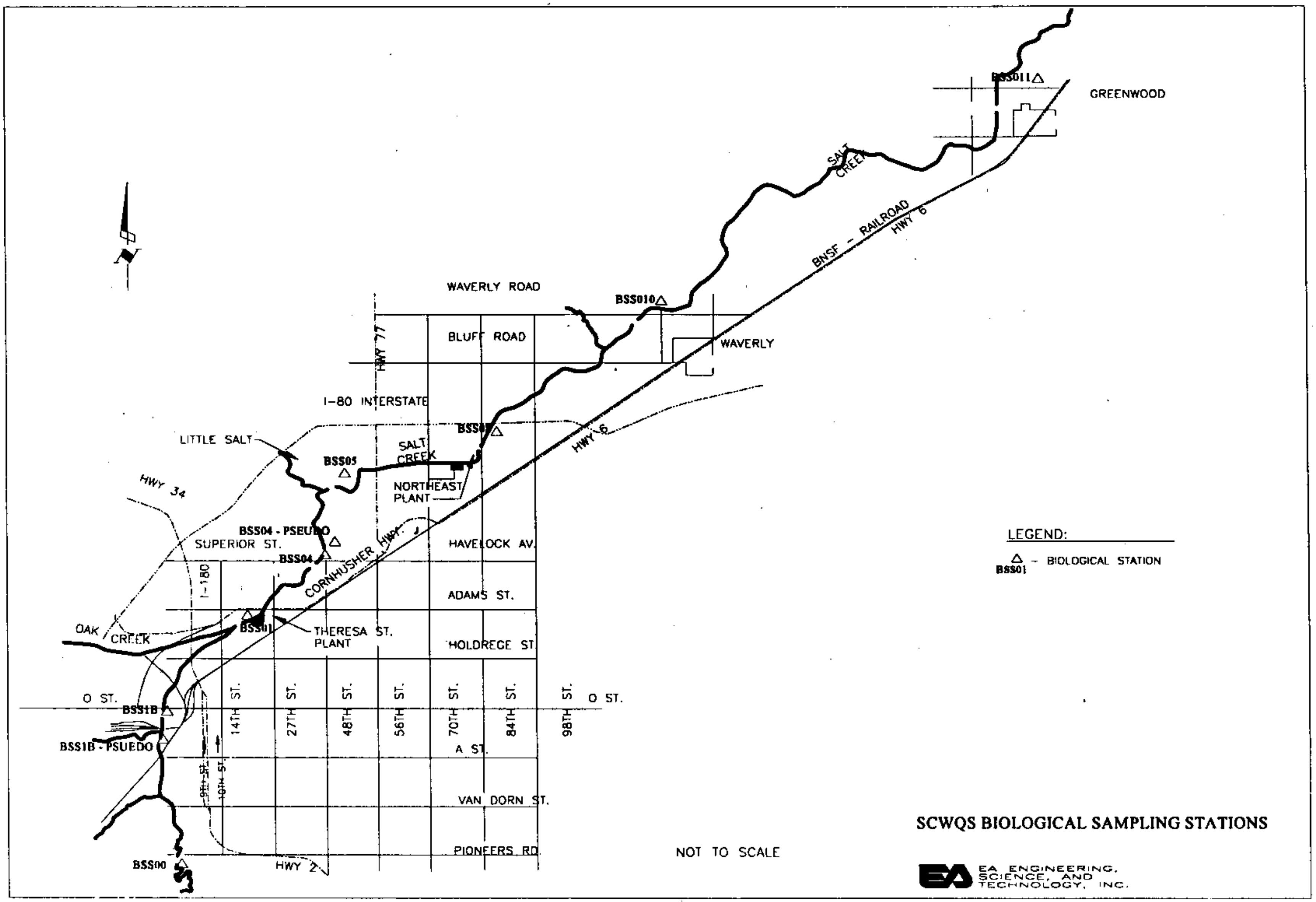


Figure 6-1 Average (+/- One Std. Deviation) Values for Select Metrics Across a Gradient of Human Influence in Eastern Nebraska Streams

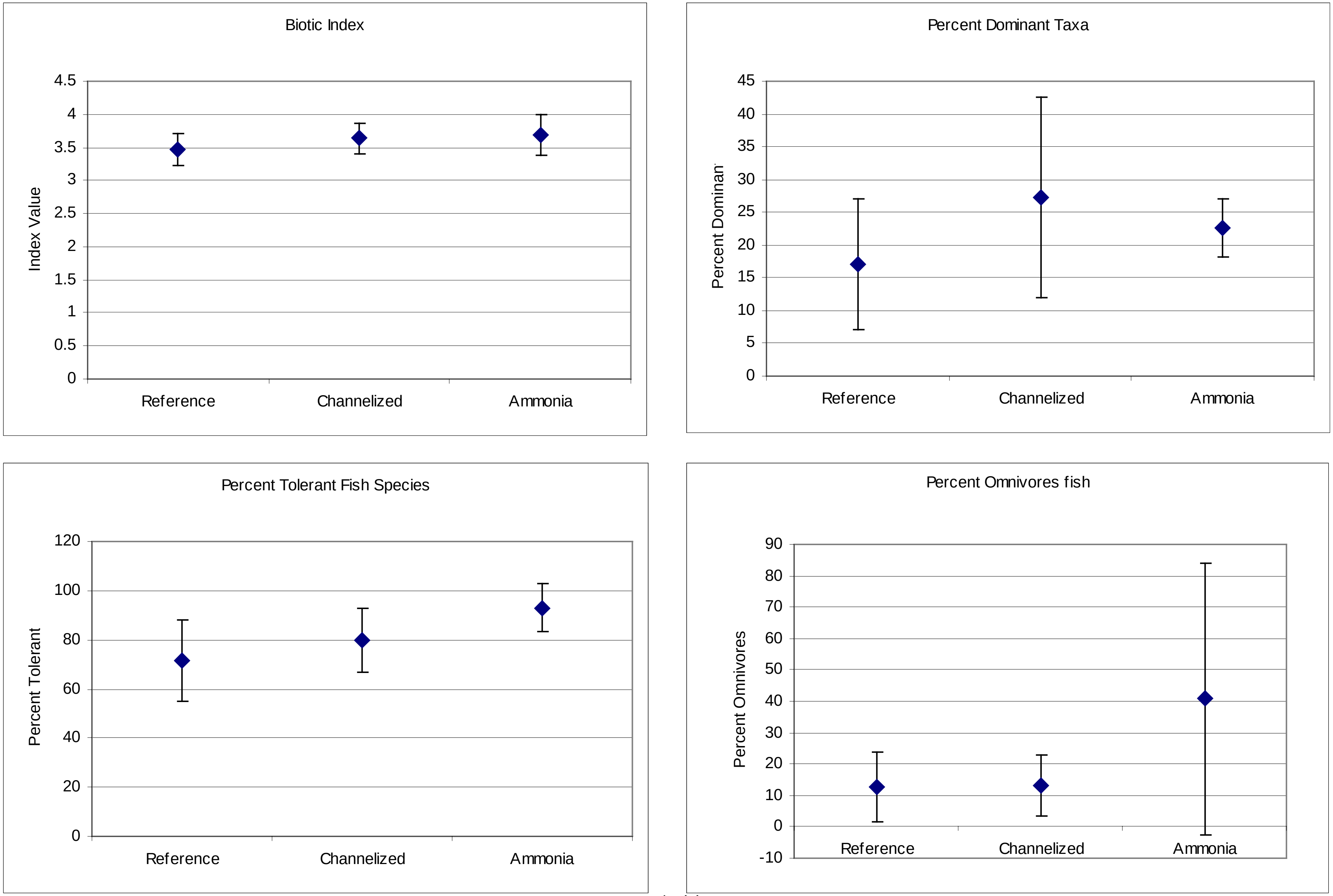


Figure 6-2 Average (+/- One Std. Deviation) Values for Select Metrics Across a Gradient of Human Influence in Eastern Nebraska Streams

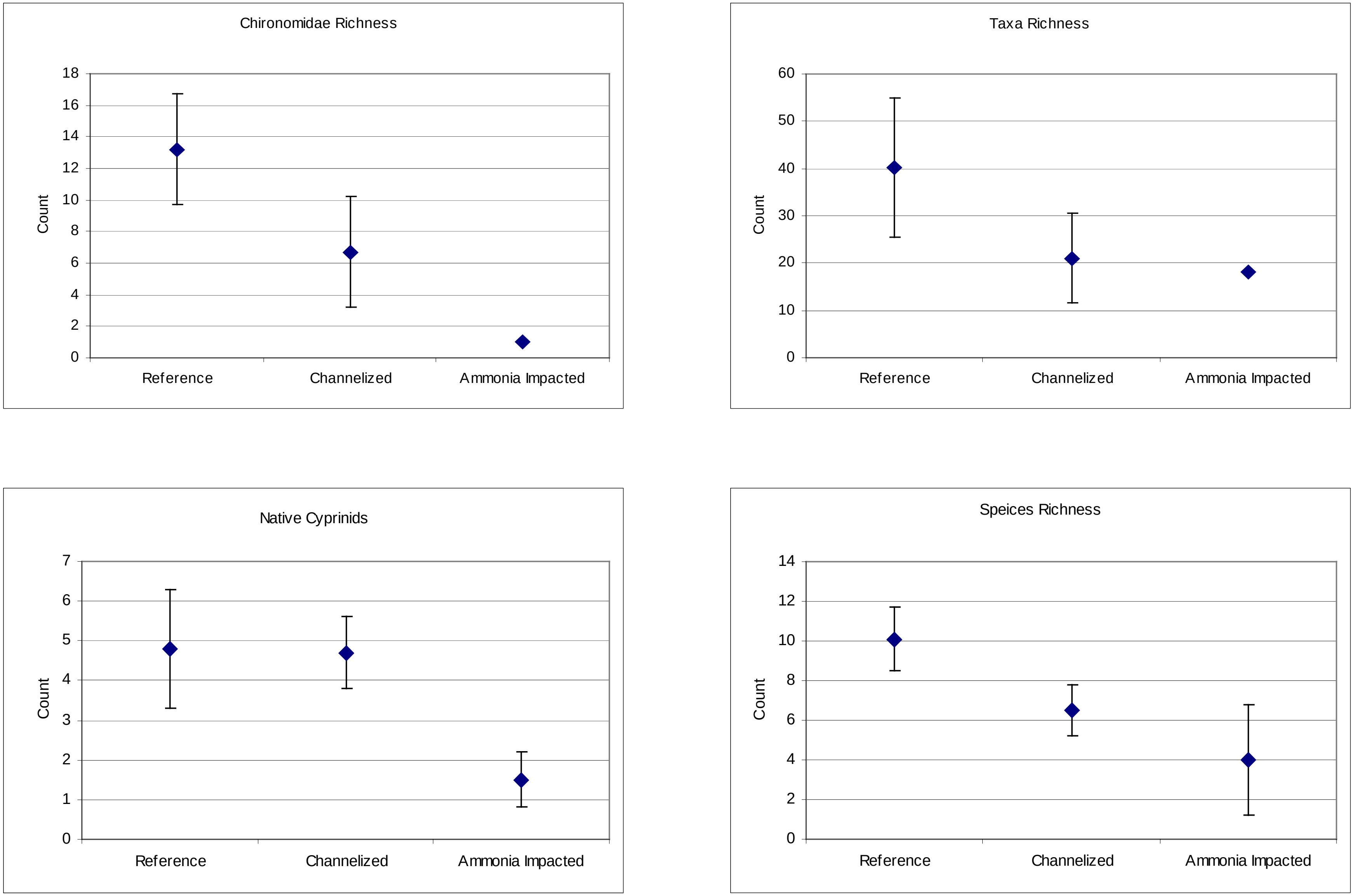


Figure 7-1 Summary of Habitat Scores, Width/Depth Ratios, Depth and Velocity Frequencies, and Substrate Frequencies, Salt Creek Summer Data, 1994-1999

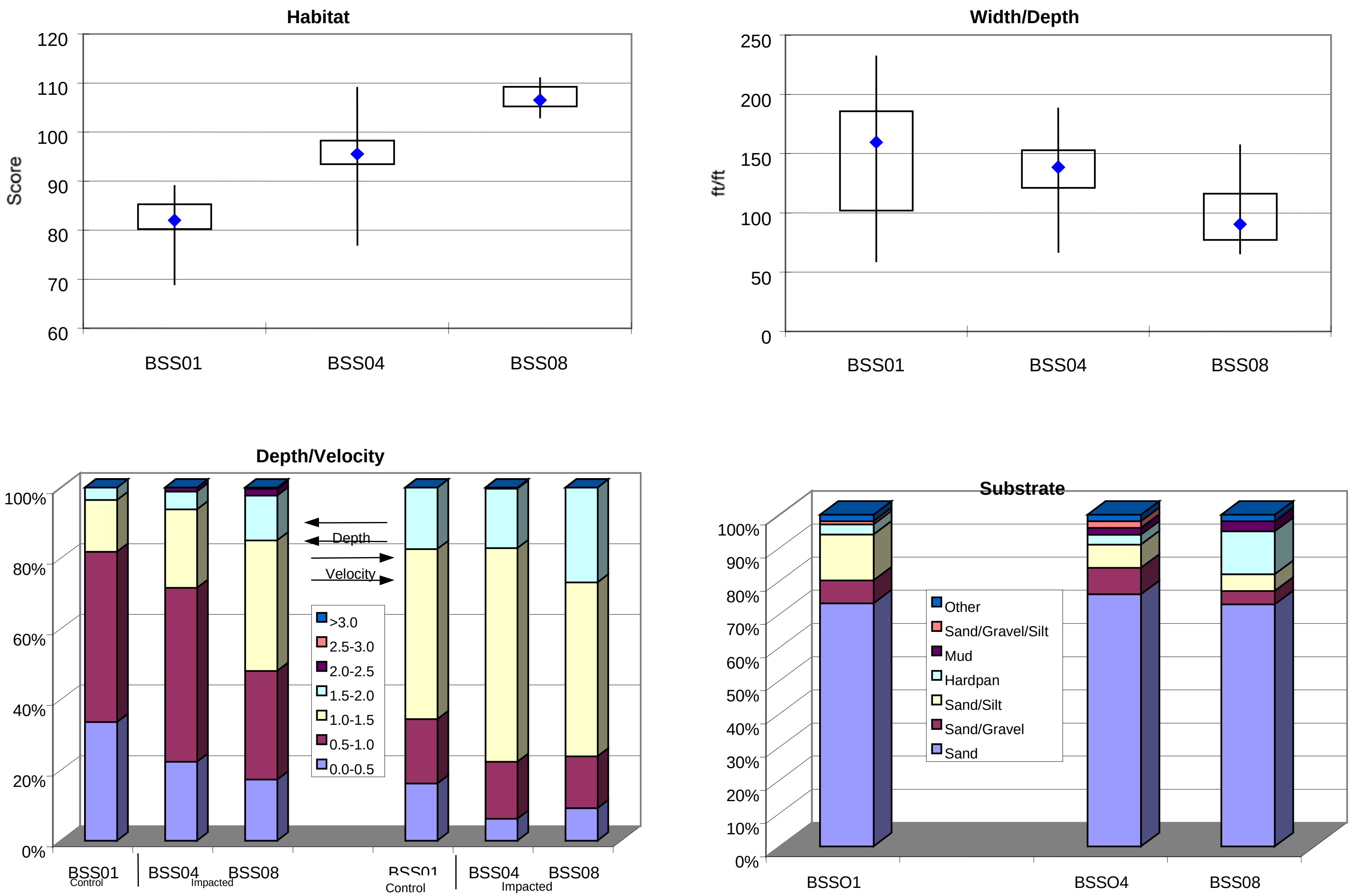


Figure 7-2 Summary of Temperature, Dissolved Oxygen, pH, Conductivity, and Chloride, Salt Creek Summer Data, 1994-1999

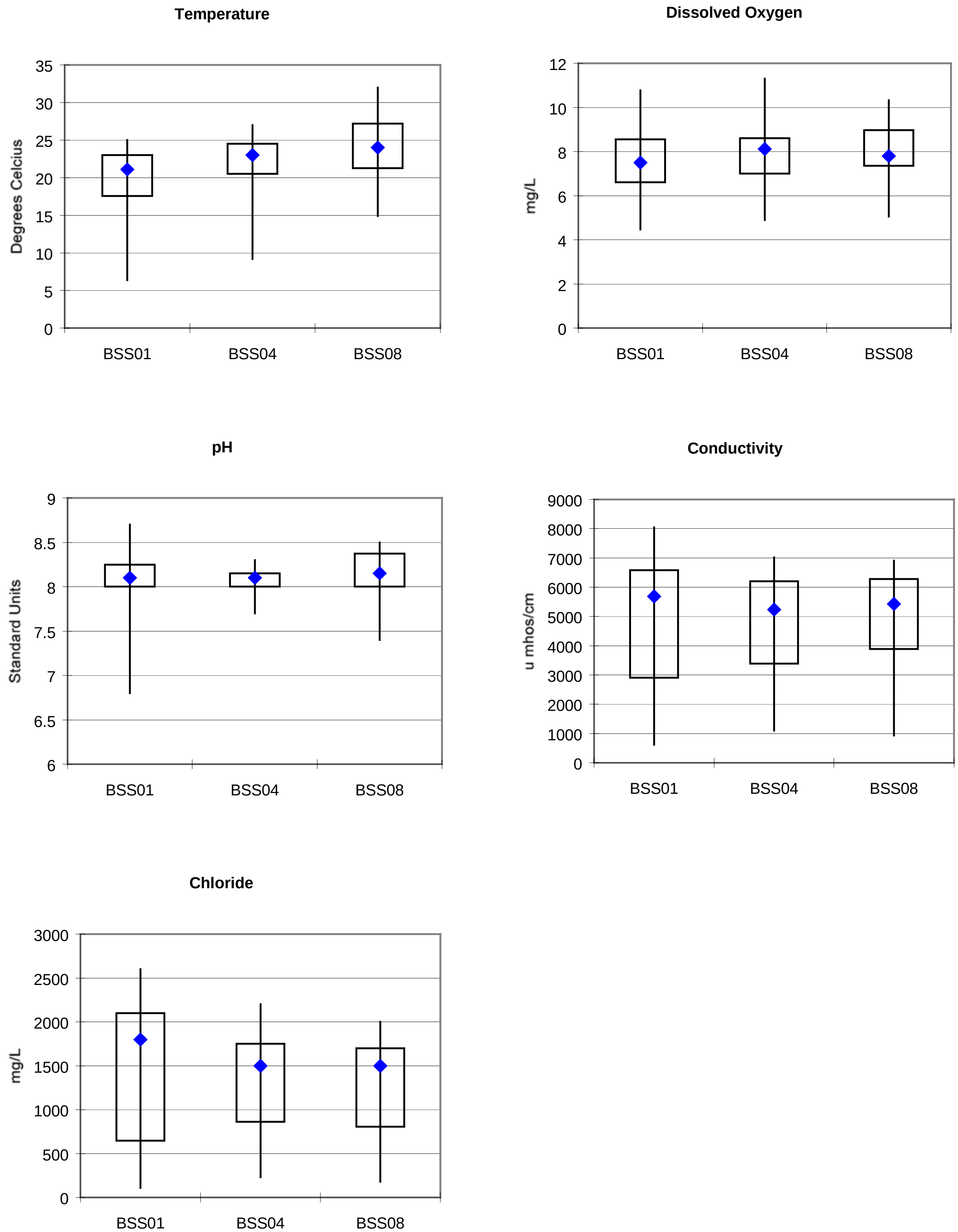
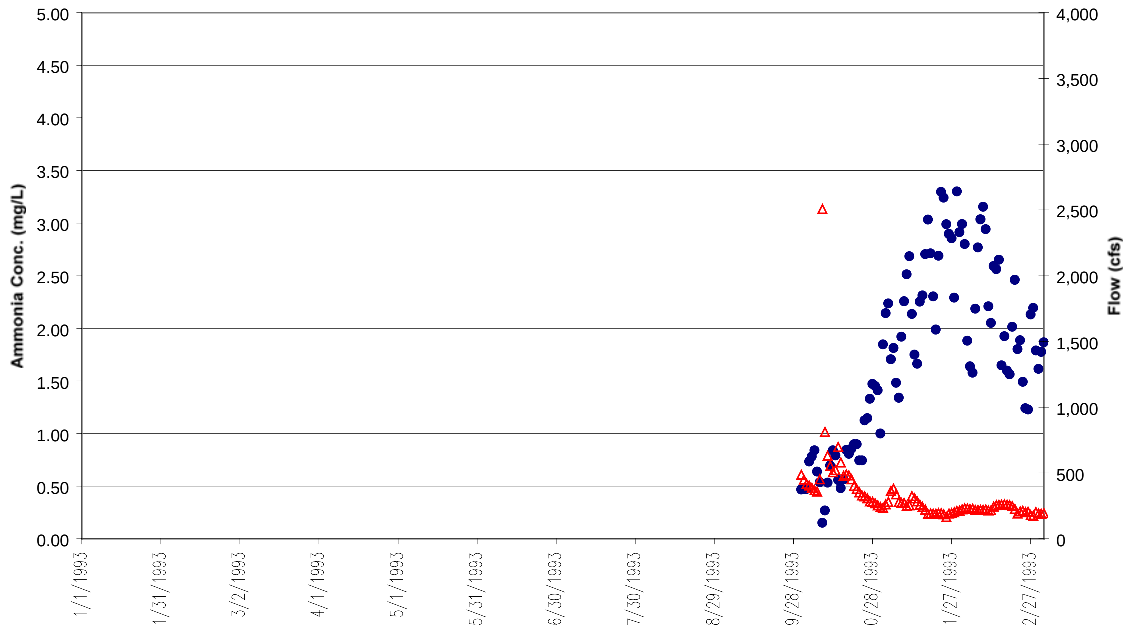


Figure 7-3A. Daily Modeled Ammonia Values, BSS08 Salt Creek 1994-1999



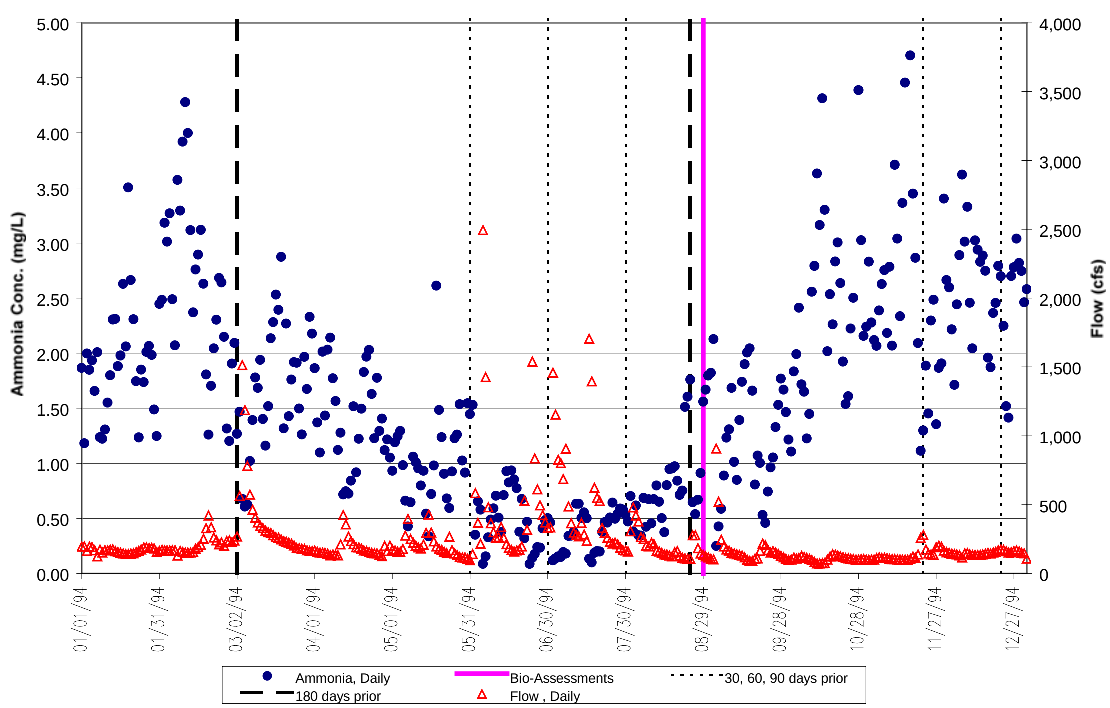
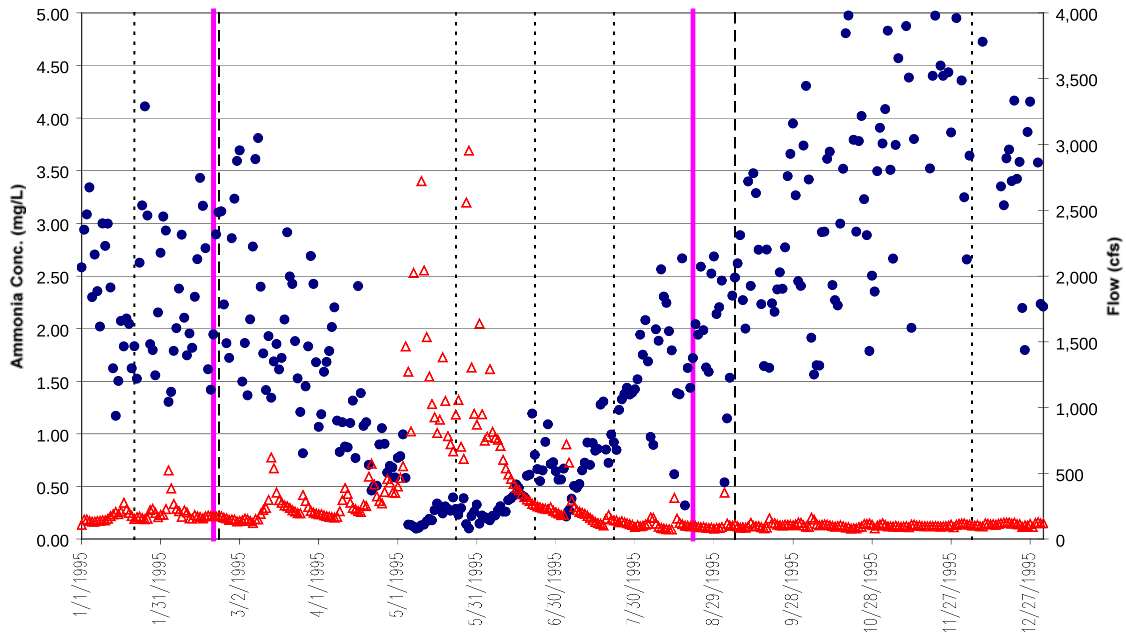


Figure 7-3A Continued



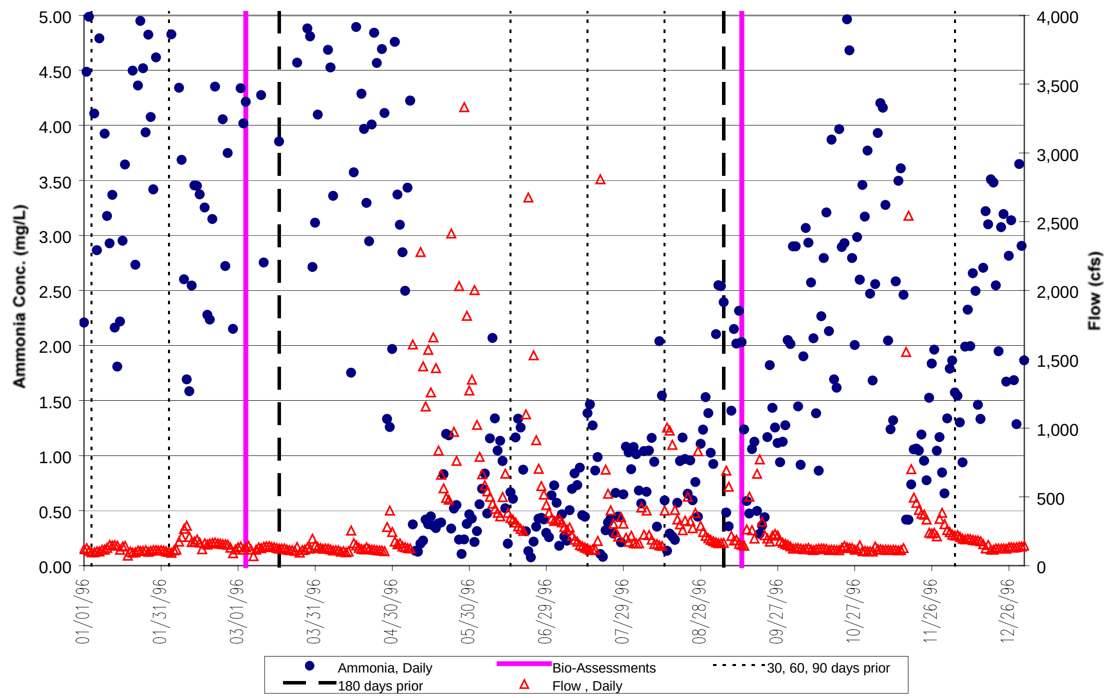
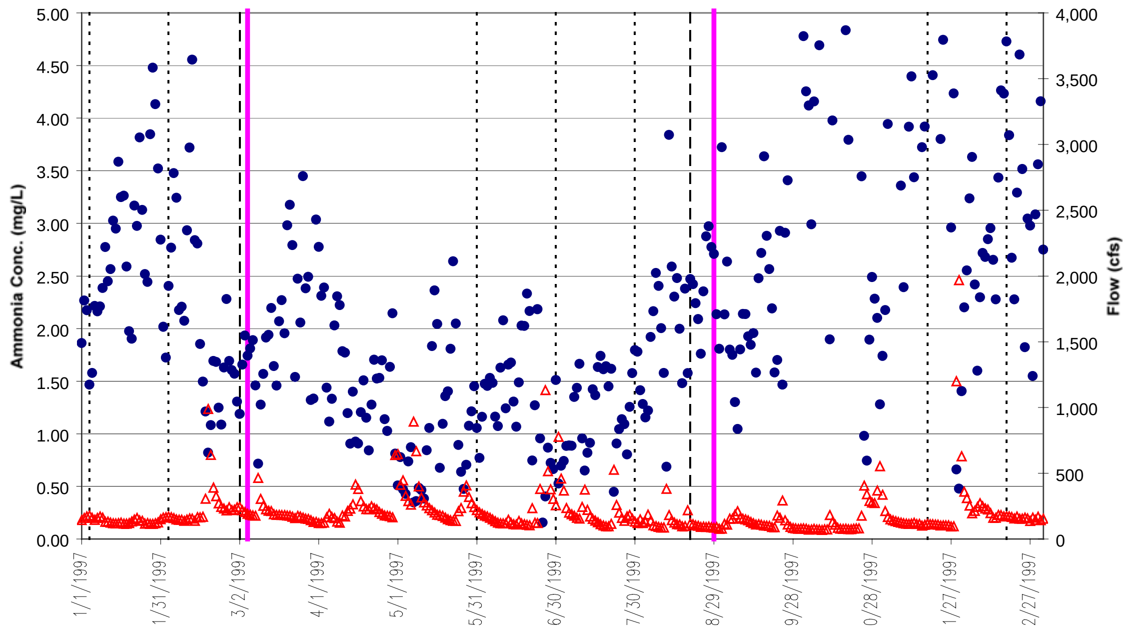


Figure 7-3A Continued



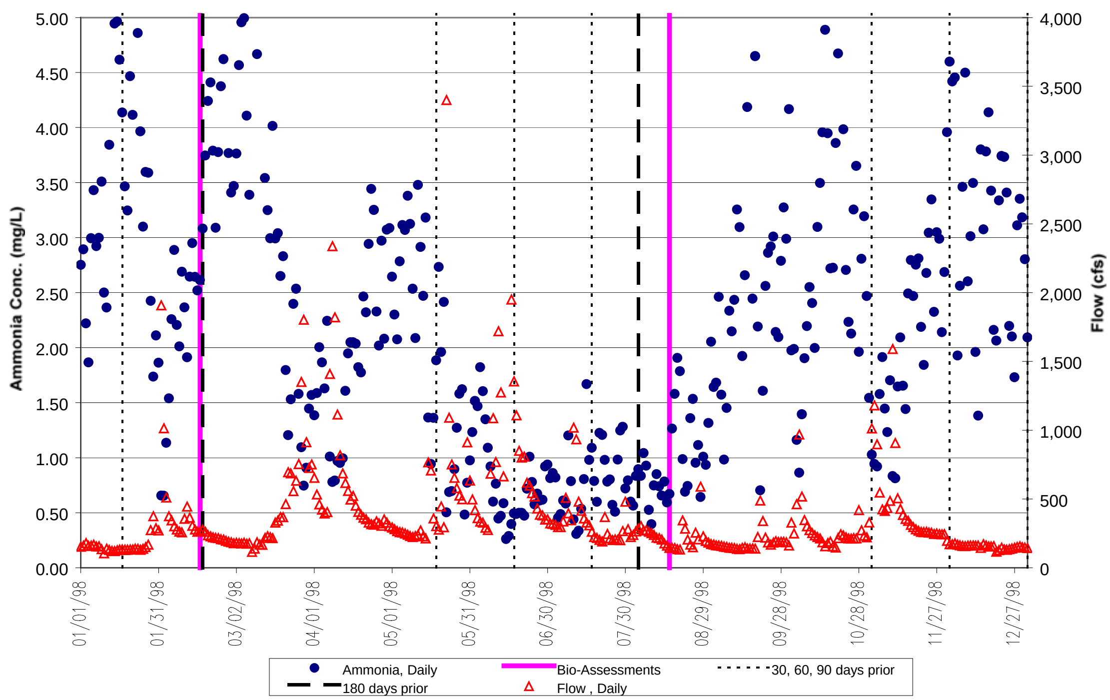


Figure 7-3A Continued

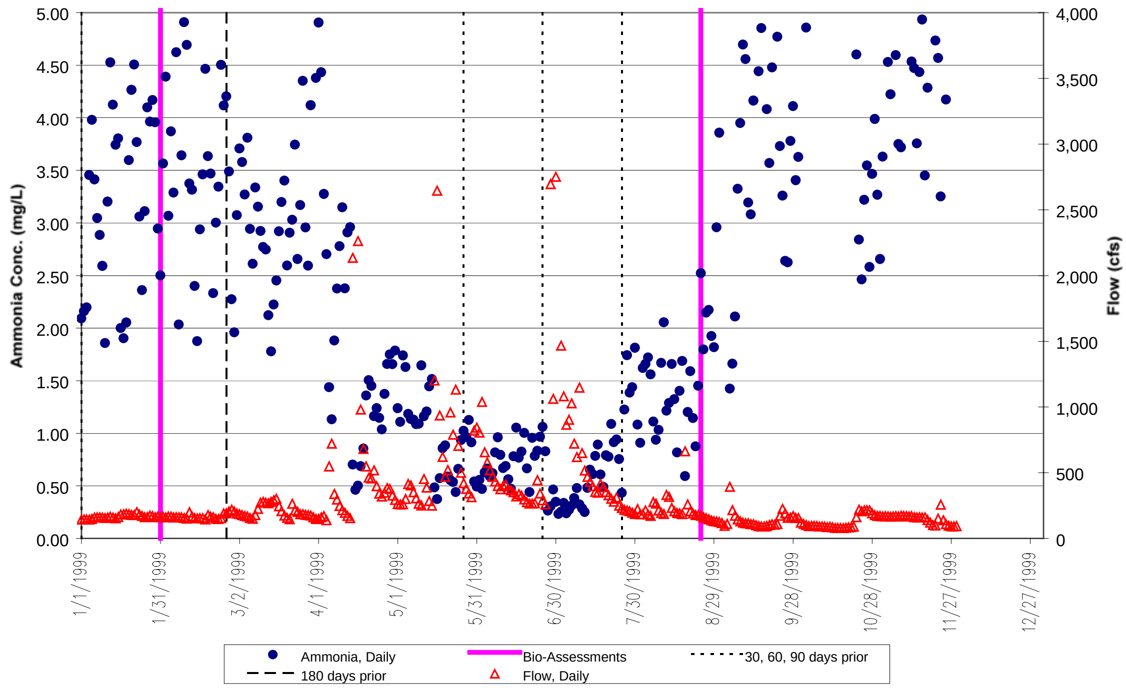
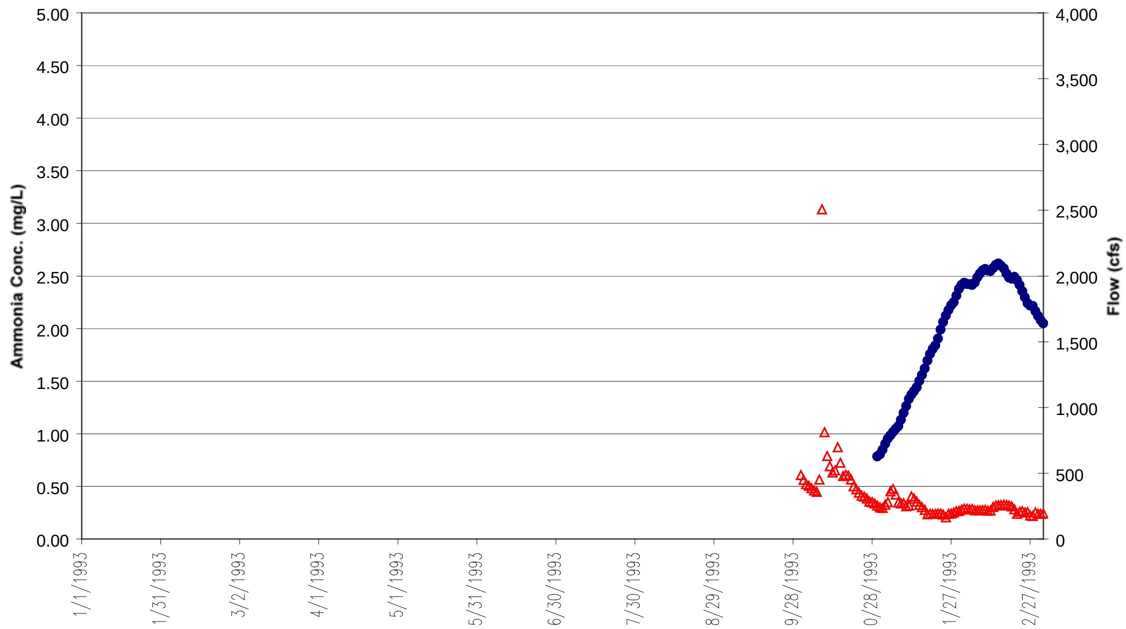


Figure 7-3B. 30-Day Average Modeled Ammonia, BSS08 Salt Creek, 1994-1999



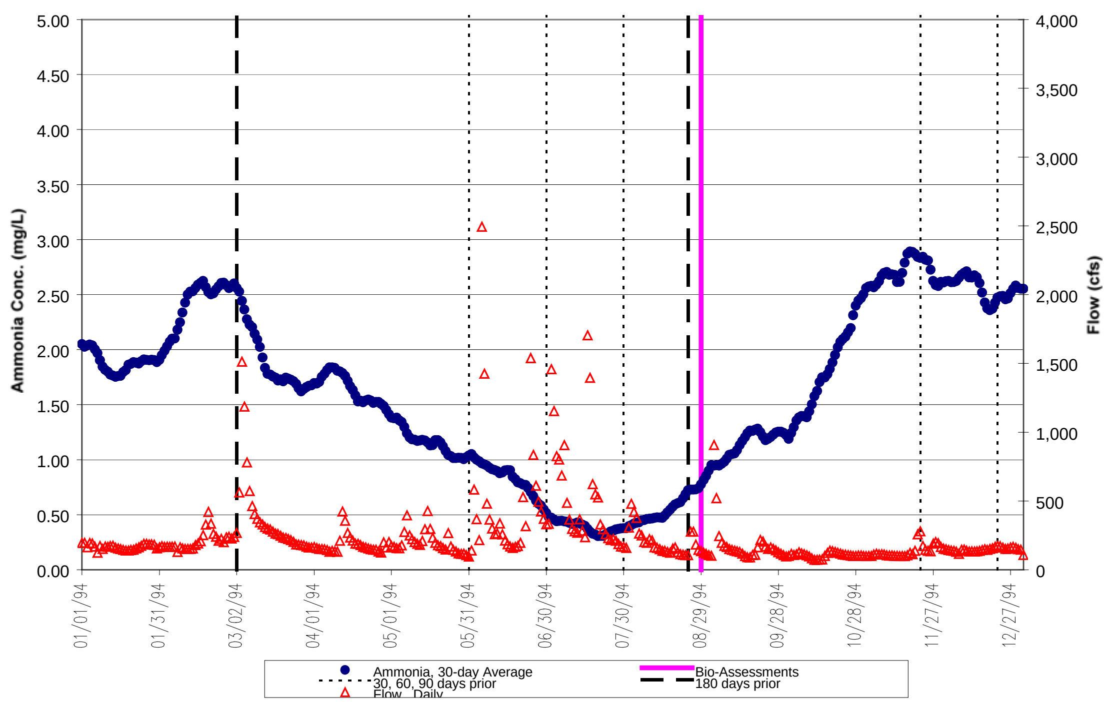
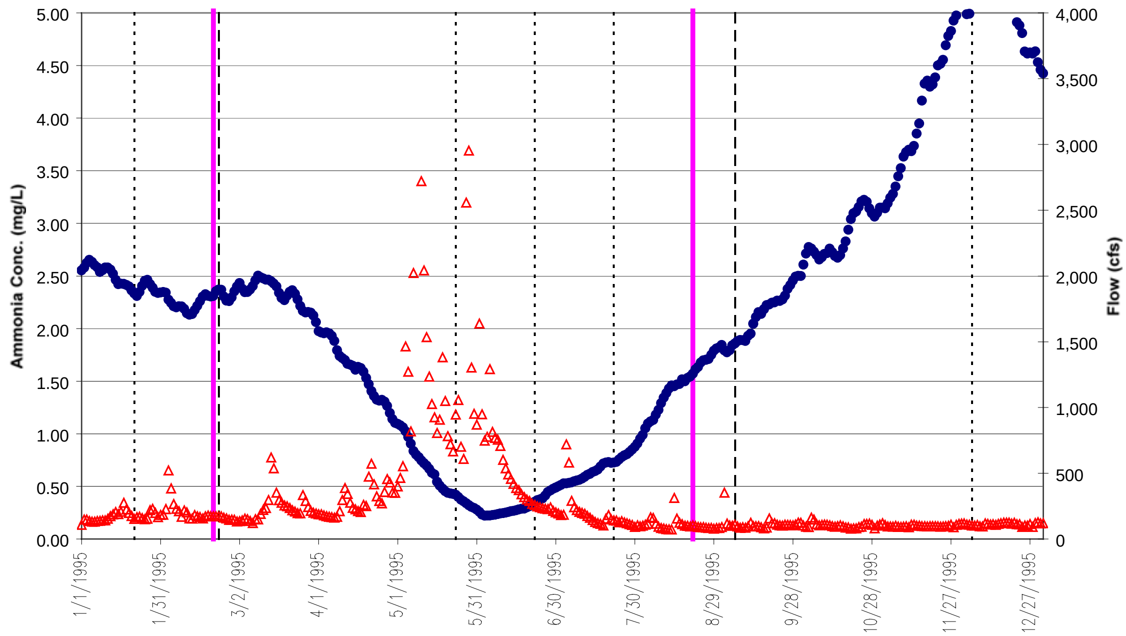


Figure 7-3B Continued



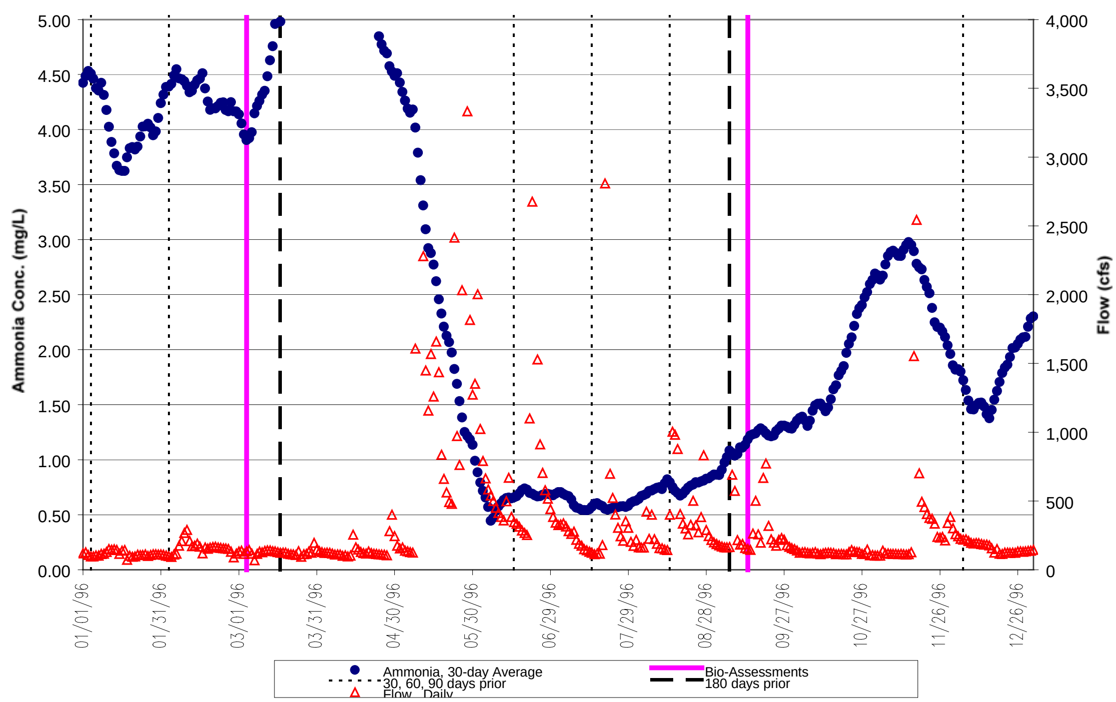
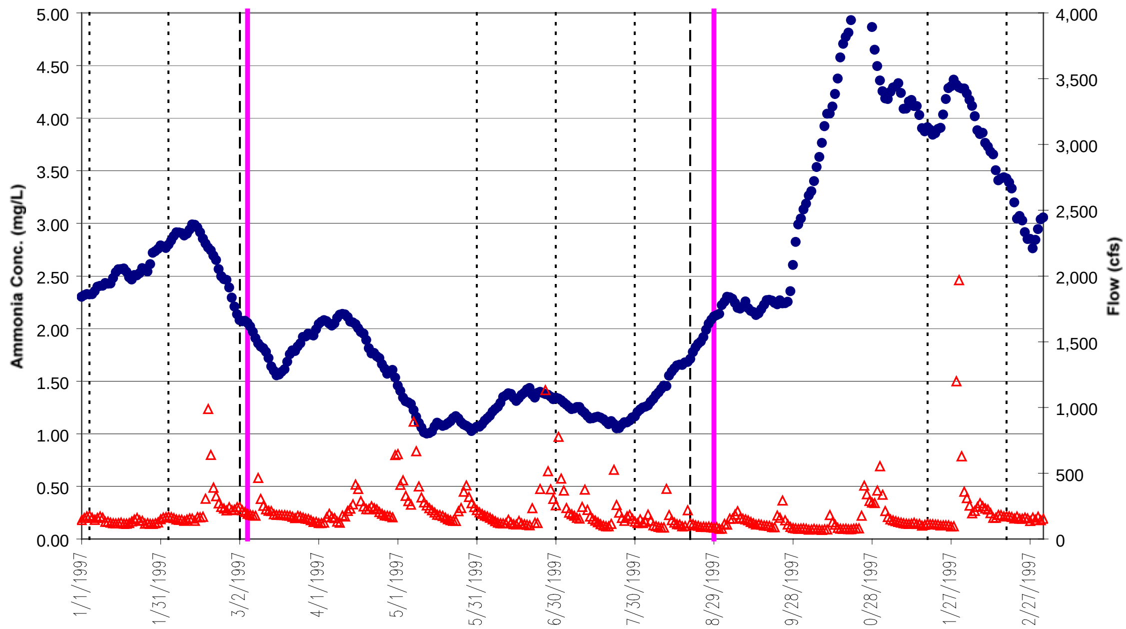


Figure 7-3B Continued



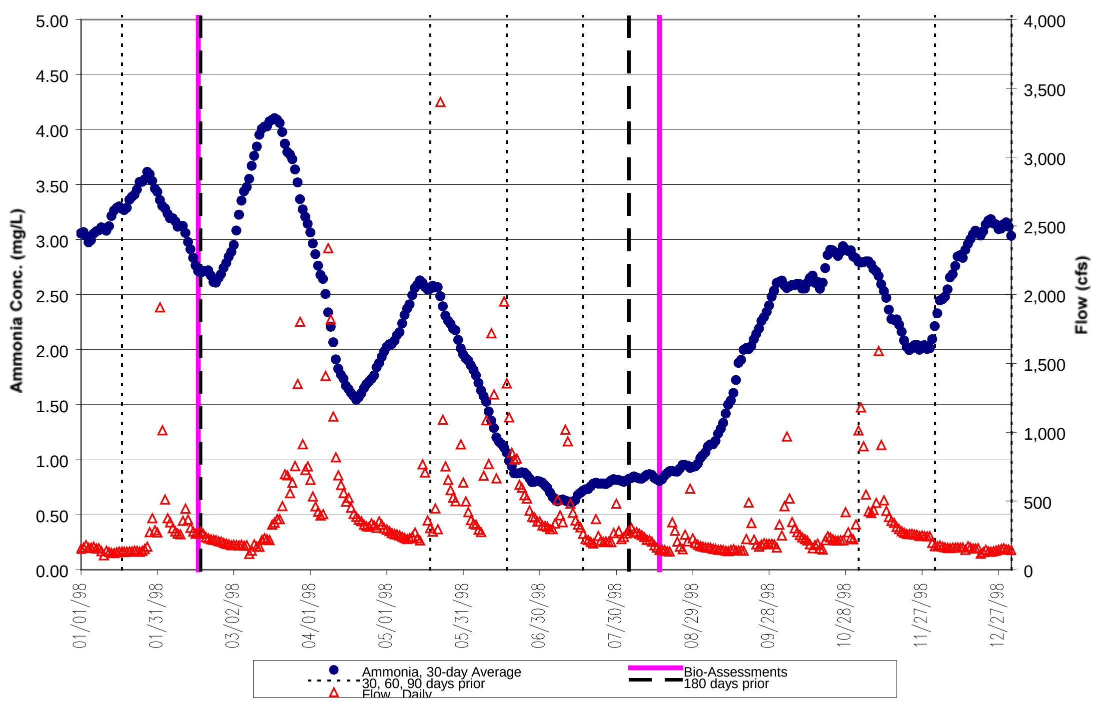


Figure 7-3B Continued

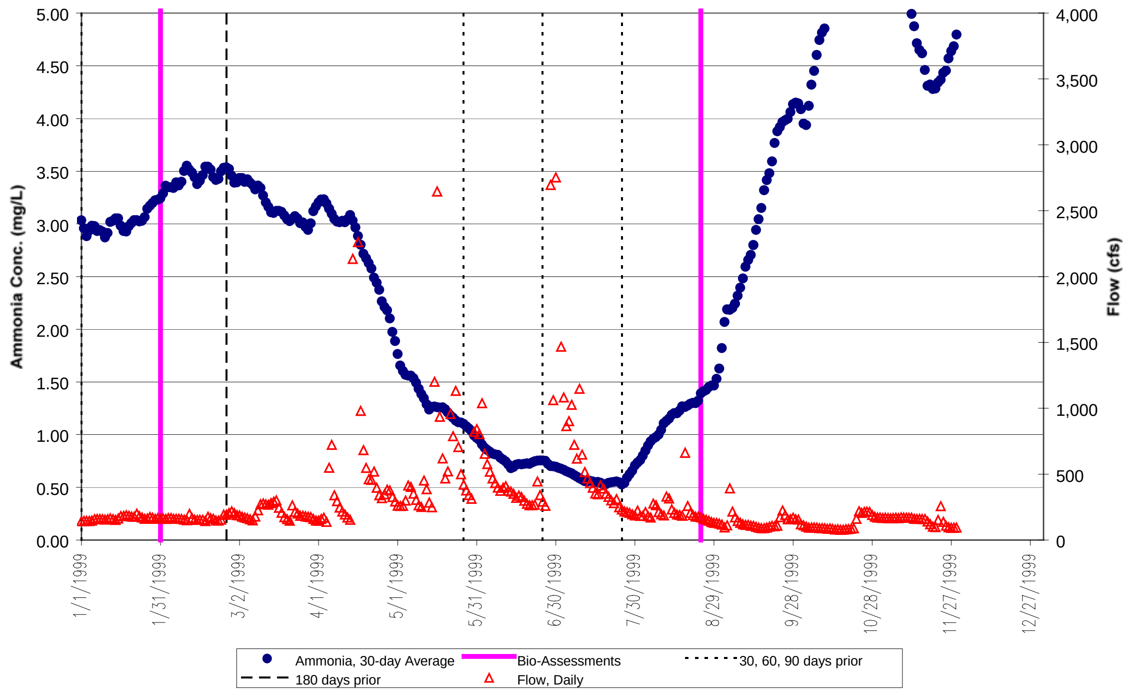


Figure 7-4. BSS08 Summer Fish Prior 180-days, Maximum 30-day Average Ammonia

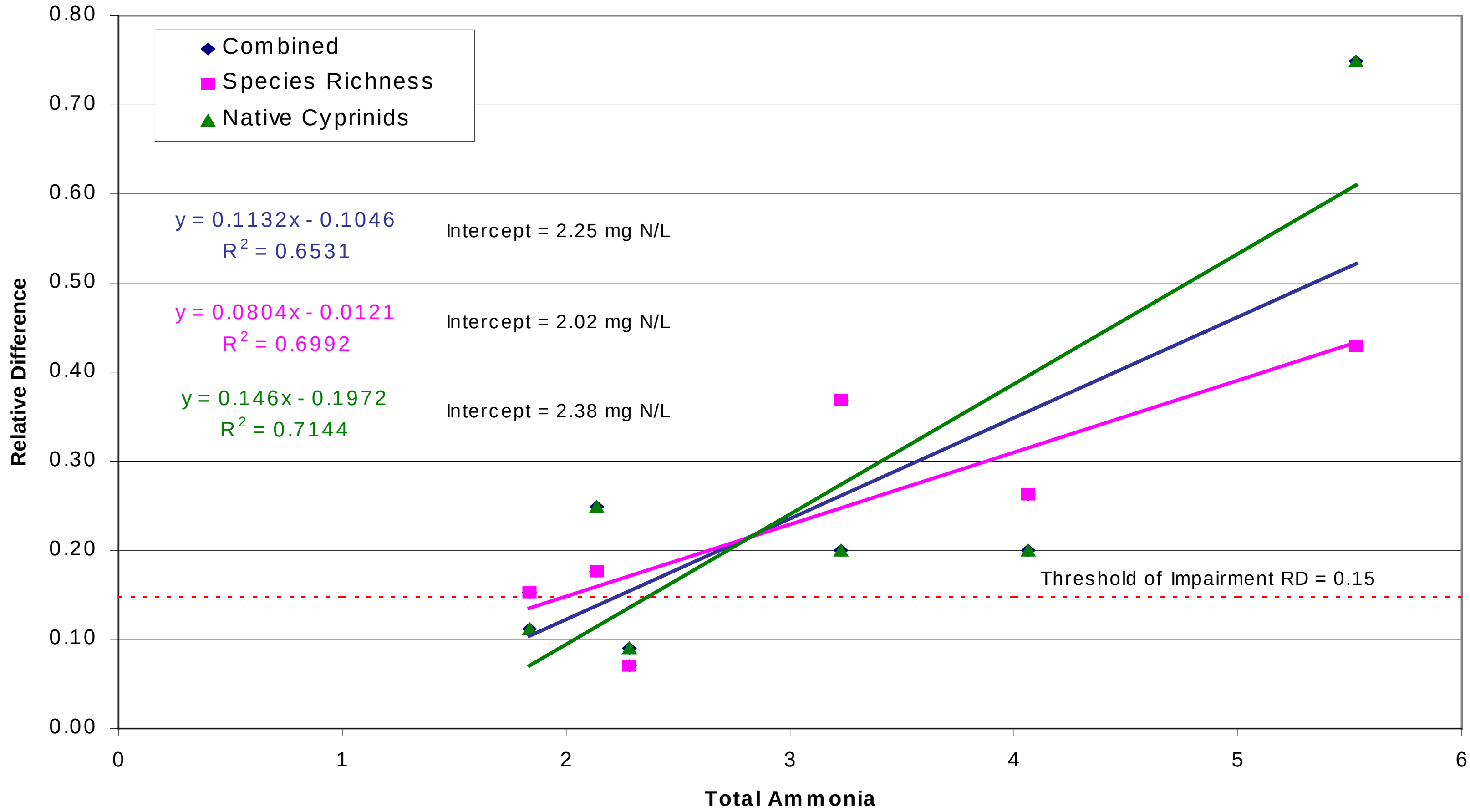


Figure 7-5. BSS04 Summer Fish Prior 180-days Maximum 30-day Average Ammonia

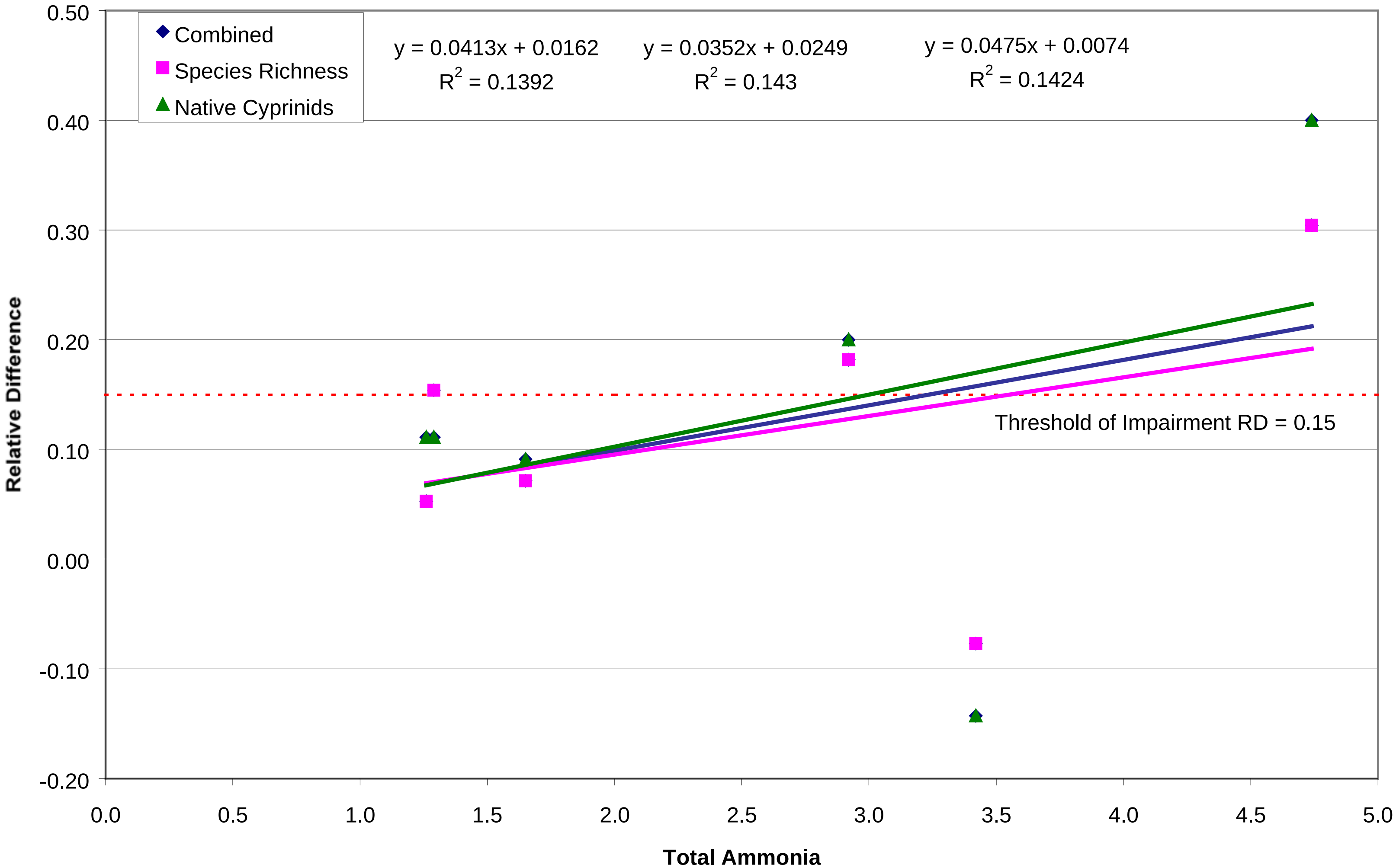
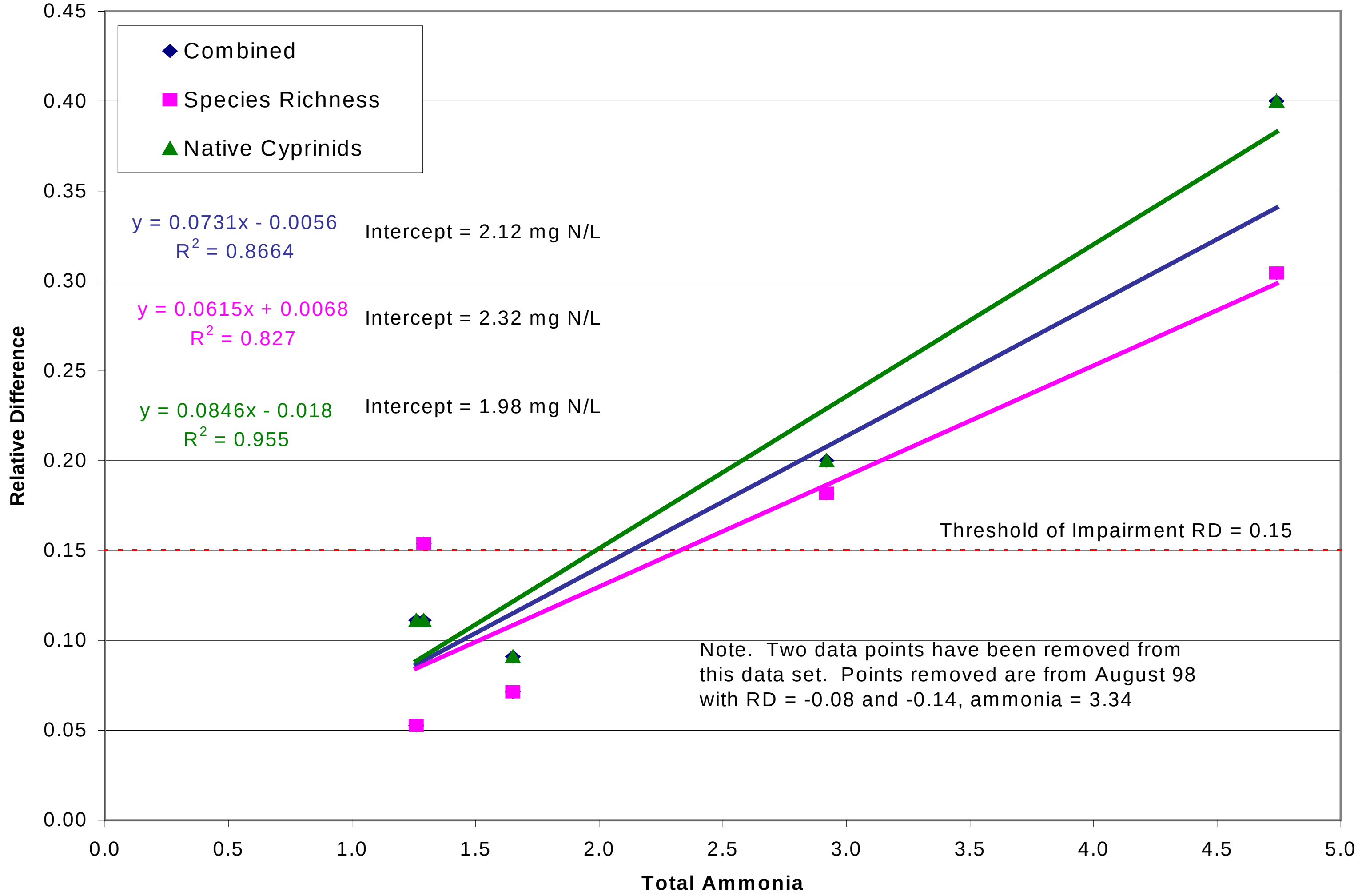


Figure 7-6. BSS04 Summer Fish Prior 180-days Maximum 30-day Average Ammonia Less August 1998 Data Points



APPENDIX A

TO

MANUSCRIPT 1

Table A-1 Summary of Salt Creek Physical Data & Pseudoreplicate Stations

Station	Average					Range Among Transects				
	Width (W) (ft.)	Depth (D) (ft.)	Vel. (fps)	Flow (cfs)	W/D Ratio	Width (W) (ft.)	Depth (D) (ft.)	Vel. (fps)	Flow (cfs)	W/D Ratio
March 5, 1997 Measurements										
BSS1B	136	0.76	1.11	127.8	178	127 - 156	0.1 - 2.5	0.2 - 2.8	118 - 145	155 - 205
BSS1B Pseudo	83	1.58	0.94	125.5	54	78 - 91	0.7 - 3.4	0.09 - 1.5	122 - 131	39 - 66
BSS08	108	1.42	1.30	202.5	77	105 - 115	0.3 - 2.9	0.5 - 1.8	200 - 206	70 - 90
BSS08 Pseudo	102	1.51	1.23	207	67	98 - 106	0.25 - 2.5	0.2 - 1.8	203 - 213	61 - 71
August 23 and 24, 1999 Measurements										
BSS1B	86	0.51	0.96	44.3	170.9	67-96	0.3-1.2	0.42-1.57	40-48	113-204
BSS1B Pseudo	78	0.54	0.72	32.4	153.0	64-87	0.1-1.1	0.00-1.37	30-33	93-195
BSS04	122	0.94	1.20	136.6	131.3	120-125	0.3-2.3	0.00-2.02	129-143	123-136
BSS04 Pseudo	123	0.97	1.16	146.9	129.6	121-125	0.2-2.1	0.12-2.02	141-153	122-131
BSS08	108	1.37	1.41	207.5	79.7	105-113	0.2-2.7	0.48-1.87	197-222	70-89
BSS08 Pseudo	102	1.43	1.30	185.1	72.4	102-104	0.2-2.8	0.01-1.78	187-191	64-76

Table A-2 Salt Creek March 5, 1997 Frequency Distributions of Depth and Velocities at Transect Points at Pseudoreplicate Stations

Depth Frequency								
Depth Range (ft.)	BSS1B		BSS1B Pseudo		BSS08		BSS08 Pseudo	
	Points	Percent	Points	Percent	Points	Percent	Points	Percent
0-0.5	19	42.2%	0	0.0%	1	3.1%	1	3.1%
0.5-1.0	13	28.9%	4	12.1%	6	18.8%	4	12.5%
1.0-1.5	9	20.0%	14	42.4%	13	40.6%	10	31.3%
1.5-2.0	3	6.7%	9	27.3%	9	28.1%	13	10.6%
2.0-2.5	1	2.2%	3	9.1%	2	6.3%	4	12.5%
2.5-3.0	0	0.0%	0	0.0%	1	3.1%	0	0.0%
>3.0	0	0.0%	3	9.1%	0	0.0%	0	0.0%
Total	45	100.0%	33	100.0%	32	100.0%	32	100.0%
Average	0.76 ft.		1.58 ft.		1.42 ft.		1.51 ft.	
Minimum	0.10 ft.		0.70 ft.		0.30 ft.		0.25 ft.	
Maximum	2.50 ft.		3.40 ft.		2.90 ft.		2.50 ft.	
Std. Dev.	0.53 ft.		0.65 ft.		0.53 ft.		0.47 ft.	

Velocity Frequency								
Velocity Range (fps)	BSS1B		BSS1B Pseudo		BSS08		BSS08 Pseudo	
	Points	Percent	Points	Percent	Points	Percent	Points	Percent
0-0.5	8	17.8%	6	18.2%	0	0.0%	1	3.1%
0.5-1.0	16	35.6%	10	30.3%	7	21.9%	8	25.0%
1.0-1.5	11	24.4%	16	48.5%	14	42.8%	16	50.0%
1.5-2.0	6	13.3%	1	3.0%	11	34.4%	7	21.9%
2.0-2.5	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2.5-3.0	4	8.9%	0	0.0%	0	0.0%	0	0.0%
>3.0	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	45	100.0%	33	100.0%	32	100.0%	32	100.0%
Average	1.11 fps		0.94 fps		1.30 fps		1.29 fps	
Minimum	0.25 fps		0.09 fps		0.53 fps		0.22 fps	
Maximum	2.80 fps		1.56 f ps		1.85 fps		1.79 fps	
Std. Dev.	0.65 fps		0.36 fps		0.33 fps		0.37fps	
Ave.Flow	127 cfs		125 cfs		202 cfs		207cfs	

Table A-2 (Cont'd) Salt Creek August 23 and 24, 1999 Frequency Distributions of Depth and Velocities at Transect Points at Pseudoreplicate Stations

Depth Frequency

Depth Range (ft.)	BSS1B		BSS1B Pseudo		BSS04		BSS04 Pseudo		BSS08		BSS08 Pseudo	
	Points	Percent	Points	Percent	Points	Percent	Points	Percent	Points	Percent	Points	Percent
0-0.5	24	68.6%	22	56.4%	8	17.4%	10	20.8%	2	4.4%	2	4.4%
0.5-1.0	10	28.6%	16	41.0%	23	50.0%	17	35.4%	5	11.1%	12	26.7%
1.0-1.5	1	2.9%	1	2.6%	11	23.9%	16	33.3%	25	55.6%	15	33.3%
1.5-2.0	0	0.0%	0	0.0%	2	4.3%	4	8.3%	10	22.2%	5	11.1%
2.0-2.5	0	0.0%	0	0.0%	2	4.3%	1	2.1%	2	4.4%	9	20.0%
2.5-3.0	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	2.2%	2	4.4%
>3.0	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	35	100.0%	39	100.0%	46	100.0%	48	100.0%	45	100.0%	45	100.0%
Ave.	0.51 ft.		0.54 ft.		0.94 ft.		0.97 ft.		1.37 ft.		1.43 ft.	
Min.	0.30 ft.		0.10 ft.		0.30 ft.		0.20 ft.		0.20 ft.		0.20 ft.	
Max.	1.20 ft.		1.10 ft.		2.30 ft.		2.10 ft.		2.70 ft.		2.80 ft.	
Std.Dev.	0.22 ft.		0.23 ft.		0.44 ft.		0.48 ft.		0.45 ft.		0.63 ft.	

Velocity Frequency

Vel. Range fps	BSS1B		BSS1B Pseudo		BSS04		BSS04 Pseudo		BSS08		BSS08 Pseudo	
	Points	Percent	Points	Percent	Points	Percent	Points	Percent	Points	Percent	Points	Percent
0-0.5	4	11.4%	10	25.6%	3	6.5%	5	10.4%	1	2.2%	3	6.7%
0.5-1.0	16	45.7%	20	51.3%	9	19.6%	10	20.8%	3	6.7%	4	8.9%
1.0-1.5	13	37.1%	9	23.1%	28	60.9%	22	45.8%	22	48.9%	24	53.3%
1.5-2.0	2	5.7%	0	0.0%	5	10.9%	10	20.8%	19	42.2%	14	31.1%
2.0-2.5	0	0.0%	0	0.0%	1	2.2%	1	2.1%	0	0.0%	0	0.0%
2.5-3.0	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
>3.0	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	35	100.0%	39	100.0%	46	100.0%	48	100.0%	45	100.0%	45	100.0%
Ave.	0.96 fps		0.72 fps		1.20 fps		1.16 fps		1.41 fps		1.30 fps	
Min.	0.42 fps		0.00 fps		0.00 fps		0.12 fps		0.48 fps		0.01 fps	
Max.	1.57 fps		1.37 fps		2.02 fps		2.02 fps		1.87 fps		1.78fps	
Std.Dev.	0.33 fps		0.33 fps		0.39 fps		0.46 fps		0.31 fps		0.42 fps	
Ave. Flow	44.3 cfs		32.4 cfs		136.6 cfs		136.6 cfs		207.5 cfs		185.1 cfs	

Table A-3 Salt Creek March 6 and 7, 1997 Taxonomic List and Abundance of Fish Collected from Pseudoreplicate Stations

Family		Common Name	Genus Species	BSS01B	Pseudo	BSS08	Pseudo
Cyprinidae	Minnows	red shiner	*Cyprinella lutrensis*	170	19	62	102
Cyprinidae	Minnows	emerald shiner	*Notropis atherinoides*	1		3	5
Cyprinidae	Minnows	common carp	*Cyprinus carpio*	3	18	2	12
Cyprinidae	Minnows	plains minnow	*Hybognathus placitus*			4	3
Cyprinidae	Minnows	sand shiner	*Notropis ludibundus*	38	218	82	77
Cyprinidae	Minnows	river shiner	*Notropis blennius*	4		1	8
Cyprinidae	Minnows	creek chub	*Semotilus atromaculatus*			44	29
Cyprinidae	Minnows	*Hybognathus sp.*	*Hybognathus sp.**	65	35		
Cyprinidae	Minnows	fathead minnow	*Pimephales promelas*	16	20	5	5
Catostomidae	Suckers	river carpsucker	*Carpiodes carpio*	4	19		
Ictaluride	Catfish	channel catfish	*Ictalurus punctatus*		1		
Ictaluride	Catfish	black bullhead	*Ictalurus melas*			1	
Centrarchidae	Sunfish	green sunfish	*Lepomis cyanellus*	10	1	8	26
Sciaenidae	Drums	freshwater drum	*Aplodinotus grunniens*		1		
			Total Number of Fish	246	297	212	267
		Metric Values:	Species Richness	8	8	10	9
			Native Cyprinids	5	3	7	7

* Indicates that genus was not included in totals.

Table A-4 Salt Creek March 5, 1997 Metric Scores and Habitat Ratings for Pseudoreplicate Stations

Parameter	BSS1B	BSS1B Pseudo	BSS08	BSS08 Pseudo
Bottom substrate/available cover	3	2	5	4
Pool substrate characterization	8	8	8	8
Pool variability	8	10	8	8
Channel alteration	3	4	4	4
Sediment deposition	10	6	8	9
Channel sinuosity	3	4	4	2
Channel flow status	18	18	18	18
Bank Stability				
Left bank	9	9	4	4
Right bank	9	9	4	4
Bank vegetative protection				
Left bank	9	9	4	4
Right bank	9	9	6	4
Riparian vegetative zone width				
Left bank	7	7	9	10
Right bank	7	7	9	10
Total Score	103	102	91	89

Table A-4 (Continued) Salt Creek August 23 – 27, 1999 Metric Scores and Habitat Ratings for Pseudoreplicate Stations

Parameter	BSS1B	BSS1B Pseudo	BSS04	BSS04 Pseudo	BSS08	BSS08 Pseudo
Bottom substrate/available cover	8	7	6	6	8	7
Pool substrate characterization	7	6	7	7	7	8
Pool variability	6	8	6	6	6	6
Channel alteration	6	6	5	5	7	6
Sediment deposition	7	6	7	7	8	7
Channel sinuosity	7	6	6	6	7	7
Channel flow status	8	10	15	15	17	16
Bank stability						
Left bank	9	9	8	8	8	9
Right bank	9	10	9	9	8	8
Bank vegetative protection						
Left bank	7	7	7	7	7	9
Right bank	7	8	7	7	8	8
Riparian vegetative zone width						
Left bank	8	9	8	8	8	8
Right bank	8	8	8	8	8	7
Total Score	97	100	99	99	107	106

Table A-5 Salt Creek March 5, 1997 Taxonomic List and Abundance of Marcoinvertebrate Species Collected from Pseudoreplicate Stations

Phylum	Class	Order	Family	Genus/Species	BSS1B		BSS1B Pseudo		BSS08	BSS08 Pseudo
					Subsample	All	Subsampl e	All	All	All
Annelida	Oligochaeta				21	20	26	28	4	5
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Berosus sp.	1	1				
Arthropoda	Insecta	Coleoptera	Dytiscidae	Dytiscidae			1	1		
Arthropoda	Insecta	Diptera	Chironomidae	Pseudosmitta					1	
Arthropoda	Insecta	Diptera	Chironomidae	Larsia/Natarsia	1	1				
Arthropoda	Insecta	Diptera	Chironomidae	Paraphaenocladius			10	17	4	2
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum fallax						1
Arthropoda	Insecta	Diptera	Chironomidae	Rheocricotopus robacki	5	4	1	1	1	
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsus	16	13	23	38	3	
Arthropoda	Insecta	Diptera	Chironomidae	Parakiefferiella			1	1		
Arthropoda	Insecta	Diptera	Chironomidae	Parametriocnemus	5	4	6	5	14	12
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladius	60	57	78	100	7	16
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus (C.)	16	13	10	10	23	16
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus (Isocladius)					20	10
Arthropoda	Insecta	Diptera	Chironomidae	Hydrobaenus	68	65	54	90	44	50
Arthropoda	Insecta	Diptera	Chironomidae	Cryptochironomus	1	1				
Arthropoda	Insecta	Diptera	Chironomidae	Thienemannimyia grp.	1	1	26	24	3	1
Arthropoda	Insecta	Diptera	Chironomidae	Chironomus	6	5	1	2	6	5
Arthropoda	Insecta	Diptera	Chironomidae	Dipocladius	9	8	6	4	4	2
Arthropoda	Insecta	Diptera	Chironomidae	Ablabesmyia mallochi					1	
Arthropoda	Insecta	Diptera	Chironomidae	Glyptotendipes				1	1	
Arthropoda	Insecta	Diptera	Chironomidae	Dicrotendipes neomodestus	4	3			14	9
Arthropoda	Insecta	Diptera	Muscidae	Muscidae	1	1				
Arthropoda	Insecta	Diptera	Simulidae	Simulium	35	33	17	34	4	1
Arthropoda	Insecta	Diptera	Tabanidae	Chrysops	1	1	1	1		
Arthropoda	Insecta	Diptera	Tipulidae	Tipula						1
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema terminatum			1	1		
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenacron sp.			1	1		
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara sp.	4	4	2	2		6
Arthropoda	Insecta	Odonata	Gomphidae	Gomphus	1	1	1	1		
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche simulans		1	1	1		
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Potamyia flava		2		1		
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche sp.	3	3	3	3		2
Actual Total Benthos					---	242	---	367	154	139
Extrapolated Total Benthos					259	---	270	---	---	---
Metric Values: Taxa Richness					20	22	21	23	17	16
Chironomidae Richness					12	12	11	12	15	11

Table A-6 Taxonomic List and Abundance of Fish Collected from Pseudoreplicate Stations on Salt Creek, August 25 - 27, 1999

Family		Common Name	Genus Species	BSS01B	BSS1B Pseudo	BSS04	BSS04 Pseudo	BSS08	BSS08 Pseudo
Lepisosteidae	Gars	shortnose gar	*Lepisosteus platostomus*	1	1	3	2		
Clupeidae	Herring	gizzard shad	*Dorosoma cepedianum*	19	49	1			
Hiodontidae	Mooneye	goldeye	*Hiodon alosoides*	1					
Cyprinidae	Minnows	red shiner	*Cyprinella lutrensis*	18	33	6	15	14	1
Cyprinidae	Minnows	emerald shiner	*Notropis atherinoides*	7		7	6	4	2
Cyprinidae	Minnows	common carp	*Cyprinus carpio*	9	31	5	5	6	8
Cyprinidae	Minnows	speckled chub	*Hybopsis aestivalis*	1					
Cyprinidae	Minnows	sand shiner	*Notropis ludibundus*	3					
Cyprinidae	Minnows	suckermouth minnow	*Phenacobius mirabilis*	1					
Cyprinidae	Minnows	fathead minnow	*Pimephales promelas*						1
Catostomidae	Suckers	river carpsucker	*Carpiodes carpio*	2	4		1	4	
Catostomidae	Suckers	quillback	*Carpiodes cyprinus*	4	2				
Catostomidae	Suckers	shorthead redhorse	*Moxostoma macrolepidotum*		1				
Ictaluride	Catfish	channel catfish	*Ictalurus punctatus*	11	14	5		3	4
Ictaluride	Catfish	flathead catfish	*Pylodictis olivaris*	2		1			
Ictaluride	Catfish	stonecat	*Noturus flavus*	2					
Centrarchidae	Sunfish	largemouth bass	*Micropterus salmoides*						
Centrarchidae	Sunfish	green sunfish	*Lepomis cyanellus*	11	15	18	14	3	6
Centrarchidae	Sunfish	bluegill	*Lepomis macrochirus*		3	3			2
Centrarchidae	Sunfish	black crappie	*Pomoxis nigromaculatus*						
Centrarchidae	Sunfish	white crappie	*Pomoxis annularis*		2				
Percidae	Perch	walleye	*Stizostedion vitreum*						
Sciaenidae	Drums	freshwater drum	*Aplodinotus grunniens*	2	3				
			Total Number of Fish	94	158	49	43	34	24
			Metric Values: Species Richness	16	12	9	6	6	7
			Native Cyprinids	5	1	2	2	2	3

Table A-7 Salt Creek August 22, 1999 Taxonomic List and Abundance of Macroinvertebrate Species Collected from Pseudoreplicate Stations

Phylum	Class	Order	Family	Genus/species	BSS1B	BSS1B Pseudo	BSS04	BSS04 Pseudo	BSS08	BSS08 Pseudo
Arthropoda	Crustacea	Amphipoda	Talitridae	Hyalella azteca	6	21	1	2	1	
Arthropoda	Crustacea	Decapoda	Palaemonidae	Palaemonetes kadiakensis		1				
Arthropoda	Insecta	Coleoptera	Dryopidae	Helichus sp.	6	1		9	14	7
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporus sp.		1				
Arthropoda	Insecta	Coleoptera	Dytiscidae	Laccophilus maculosus			1	3		
Arthropoda	Insecta	Coleoptera	Elmidae	Dubiraphia vittata grp.	5		5		3	1
Arthropoda	Insecta	Coleoptera	Elmidae	Macronychus glabratus	21	8	1	6	1	5
Arthropoda	Insecta	Coleoptera	Elmidae	Stenelmis sp.	4			4	3	
Arthropoda	Insecta	Coleoptera	Gyrinidae	Dineutus sp.				1		
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Berosus sp.	4	4	11		9	8
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Enochrus sp.					4	1
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Paracymus sp.						2
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Tropisternus sp.	3		3	4		
Arthropoda	Insecta	Diptera	Ceratopogonidae	Atrichopogon sp.						
Arthropoda	Insecta	Diptera	Chironomidae	Ablabesmyia mallochi						3
Arthropoda	Insecta	Diptera	Chironomidae	Chironomus sp.		21		12	27	43
Arthropoda	Insecta	Diptera	Chironomidae	Cladotanytarsus mancus sp.						3
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus bicinctus grp.	36	21	37	28	44	11
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus sylvestris grp.					10	
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus tremulus grp.	60	14		12	17	3
Arthropoda	Insecta	Diptera	Chironomidae	Cryptochironomus sp.						
Arthropoda	Insecta	Diptera	Chironomidae	Dicrotendipes neomodestus	68	66	37	56	38	75
Arthropoda	Insecta	Diptera	Chironomidae	Dicrotendipes simpsoni		2				
Arthropoda	Insecta	Diptera	Chironomidae	Endochironomus nigricans						
Arthropoda	Insecta	Diptera	Chironomidae	Glyptotendipes sp.	8	11	11	8	7	8
Arthropoda	Insecta	Diptera	Chironomidae	Natarsia sp.	4					
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladius sp.	4					
Arthropoda	Insecta	Diptera	Chironomidae	Paratanytarsus sp.						3
Arthropoda	Insecta	Diptera	Chironomidae	Paratrichocladius sp.						3
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum convictum	120	18	336	132	144	72
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum illinoense	52	57	336	364	65	40
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum scalaenum grp.		2				3
Arthropoda	Insecta	Diptera	Chironomidae	Procladius sp.						5
Arthropoda	Insecta	Diptera	Chironomidae	Rheocricotopus robacki			11		7	
Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus sp.	20	9	43	36	17	8
Arthropoda	Insecta	Diptera	Chironomidae	Simulium sp.						
Arthropoda	Insecta	Diptera	Chironomidae	Tanypus neopunctipennis					7	3
Arthropoda	Insecta	Diptera	Chironomidae	Tanypus sp.		2				
Phylum	Class	Order	Family	Genus/species	BSS1B	BSS1B Pseudo	BSS04	BSS04 Pseudo	BSS08	BSS08 Pseudo

Phylum	Class	Order	Family	Genus/species	BSS1B	BSS1B Pseudo	BSS04	BSS04 Pseudo	BSS08	BSS08 Pseudo
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsus glabresence grp.	12	2	64	8	58	16
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsus guerlus grp.					17	
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsus sp.						11
Arthropoda	Insecta	Diptera	Chironomidae	Thienemannimyia sp. grp.	8	7	11	8	7	5
Arthropoda	Insecta	Diptera	Chironomidae	Tribelos fuscicorne		2				
Arthropoda	Insecta	Diptera	Chironomidae		184	55	85		68	40
Arthropoda	Insecta	Diptera	Culicidae	Anopheles sp.		2				
Arthropoda	Insecta	Diptera	Empididae	Hemerodromia sp.						
Arthropoda	Insecta	Diptera	Ephydridae		4	2			14	3
Arthropoda	Insecta	Diptera	Tabanidae	Chrysops sp.			3		1	
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis intercalaris	12	7				
Arthropoda	Insecta	Ephemeroptera	Baetidae	Callibaetis sp.	8	4	2	1	7	5
Arthropoda	Insecta	Ephemeroptera	Baetidae	Centroptilum sp.		9				4
Arthropoda	Insecta	Ephemeroptera	Baetidae	Fallceon quilleri	16	3	33	12		
Arthropoda	Insecta	Ephemeroptera	Baetidae	Labiobaetis dardanus	8			4		
Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenis sp.	4					1
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Hexagenia limbata		1				
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Heptagenia sp.						
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenacron sp.	4	10				
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema integrum	4	4		5		
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema pulchellum						
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema terminatum		2				
Arthropoda	Insecta	Ephemeroptera	Isonychidae	Isonychia sp.	20	23	6			
Arthropoda	Insecta	Ephemeroptera	Tricorythidae	Tricorythodes sp.	56	28	5			
Arthropoda	Insecta	Hemiptera	Belostomatidae	Belostoma sp.	1	2	1	5		
Arthropoda	Insecta	Hemiptera	Corixidae	Palmacorixa sp.	9	4	5		7	
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara sp.						3
Arthropoda	Insecta	Hemiptera	Corixidae	Trichocorixa sp.		7		1	51	72
Arthropoda	Insecta	Hemiptera	Gerridae	Trepobates sp.	4	2				
Arthropoda	Insecta	Hemiptera	Veliidae	Rhagovelia sp.						
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalus cornutus			1		3	
Arthropoda	Insecta	Megaloptera	Sialidae	Sialas sp.					1	
Arthropoda	Insecta	Odonata	Calopterygidae	Hetaerina sp.	6			1		
Arthropoda	Insecta	Odonata	Coenagrionidae	Argia sp.		2			3	
Arthropoda	Insecta	Odonata	Coenagrionidae	Enallagma sp.	8					
Arthropoda	Insecta	Odonata	Coenagrionidae	Ischnura sp.		4	1	12	4	9
Arthropoda	Insecta	Odonata	Gomphidae	Gomphus sp.		2		1		
Arthropoda	Insecta	Odonata	Libellulidae				1			
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche sp.			5	1	4	
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche bidens	23		23			
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche orris			11			
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche simulans	46	2	10	10	14	9
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Potamyia flava			3	1	3	
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptila sp.	4					
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Ochrotrichia sp			1			
Arthropoda	Insecta	Trichoptera	Leptoceridae	Ceraclea tarsipunctata		1				
Arthropoda	Insecta	Trichoptera	Leptoceridae	Nectopsyche candida	4	4	5	6	3	3
Annelida	Hirudinea	Rhynchobdellida	Piscicolidae	Myzobdella lugubris						
Annelida	Hirudinea	Pharyngobdellida	Erpobdellidae	Mooreobdella microstoma					1	

Annelida	Oligochaeta					9	17	13	58	70
Ectoprocta	Phylactolaemata		Plumatellidae	Plumatella sp.	1					
Mollusca	Gastropoda	Basommatophora	Physidae	Physella sp.	3	23	13	4	10	5
Pelecypoda	Bivalvia	Veneroida	Sphaeriidae	Musculium sp.						
Platyhelminthes	Turbellaria					7				
Total Number of Macroinvertebrates					870	489	1139	770	752	563
Metric Values: Taxa Richness					40	46	35	32	38	36
Chironomidae Richness					11	14	10	10	14	18

Table A-8 Taxonomic List and Abundance of Macroinvertebrate Species Collected on Multiple Plate Samplers from Pseudoreplicate Stations. Collected from July 14 to August 23 1999.

Phylum	Class	Order	Family	Genus/Species	BSS01B	BSS1B Pseudo	BSS04	BSS04 Pseudo	BSS08	BSS08 Pseudo
Platyhelminthes	Turbellaria					2				
Annelida	Oligochaeta							53	279	38
Annelida	Hirudinea	Rhynchobdellida	Piscicolidae	Myzobdella lugubris						
Annelida	Hirudinea	Pharyngobdellida	Erpobdellidae	Mooreobdella microstoma						
Arthropoda	Insecta	Ephemeroptera	Isonychidae	Isonychia (Isonychia)	296	287	2	5	2	
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis intercalaris		17	64	3		
Arthropoda	Insecta	Ephemeroptera	Baetidae	Fallceon quilleri	68	149	129	183		17
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Heptagenia		2				
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenacron		1				
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema integrum	24	51	10	24	17	29
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema terminatum	5	73				
Arthropoda	Insecta	Ephemeroptera	Tricorythidae	Tricorythodes	139	312	34	19		
Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenis	1					
Arthropoda	Insecta	Odonta	Caloptrygidae	Hetaerina						
Arthropoda	Insecta	Odonta	Coenagrionidae	Argia			1	1		1
Arthropoda	Insecta	Plecoptera	Perlidae	Attaneuria ruralis						
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalus cornutus	22	36	1	1		
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche bidens	283	212	103	165	102	100
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche orris	1	16	4	17	1	
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche simulans	399	346	303	324	39	249
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	88	131	33	34	15	1
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Potamyia flava		2	3	5	4	16
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptila	1					
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus numerosus				1		
Arthropoda	Insecta	Trichoptera	Leptoceridae	Nectopsyche candida	2					
Arthropoda	Insecta	Coleptera	Dryopidae	Helichus	7	5	3	10	3	32
Arthropoda	Insecta	Coleptera	Elmidae	Macronychus glabratus	40	26		2	16	34
Arthropoda	Insecta	Coleptera	Elmidae	Stenelmis	1	19		17	18	16
Arthropoda	Insecta	Coleptera	Hydrophilidae	Berosus					22	37
Arthropoda	Insecta	Diptera	Chironomidae		128	48	192	368	248	320
Arthropoda	Insecta	Diptera	Chironomidae	Ablabesmyia mallochi	16					
Arthropoda	Insecta	Diptera	Chironomidae	Thienemannimyia grp.	80	112		256		320
Arthropoda	Insecta	Diptera	Chironomidae	Thienemanniella	16	32				
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus bicinctus grp.	400	304	480	1056	160	896
Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus tremulus grp.	16			352	256	256
Arthropoda	Insecta	Diptera	Chironomidae	Nanocladius crassicornus/rectinervis		32				
Arthropoda	Insecta	Diptera	Chironomidae	Nanocladius distinctus			64			
Arthropoda	Insecta	Diptera	Chironomidae	Rheocricotopus robacki	32	48		96	96	256
Arthropoda	Insecta	Diptera	Chironomidae	Chironomus						128
Arthropoda	Insecta	Diptera	Chironomidae	Dicrotendipes neomodestus	256	48	352	192	416	1024
Arthropoda	Insecta	Diptera	Chironomidae	Glyptotendipes	96		128	96	64	256
Arthropoda	Insecta	Diptera	Chironomidae	Goeldichironomus holoprasinus				96		
						BSS1B		**BSS04**		**BSS08**

Phylum	Class	Order	Family	Genus/Species	BSS01B	Pseudo	BSS04	Pseudo	BSS08	Pseudo
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum convictum	816	448	2880	4160	1568	5504
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum fallax grp.		16				
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum illinoense	64		800	512	320	
Arthropoda	Insecta	Diptera	Chironomidae	Polypedilum scalaenum grp.						128
Arthropoda	Insecta	Diptera	Chironomidae	Tribelos fuscicorne	16					
Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	32	32	352	448	160	320
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsus glabrescens grp.	80	48	1088	1664	1408	
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsus guerlus grp.						1024
Arthropoda	Insecta	Diptera	Chironomidae	Simulium						1
Arthropoda	Insecta	Diptera	Ephydridae				1			
Total Number of Macroinvertebrates					3425	2855	7027	10160	5214	11003
Metric Values:				**Taxa Richness**	29	28	22	28	20	25
				Chironomidae Richness	13	10	8	11	8	12
				EPT Taxa	12	13	10	11	7	6

Electronic Version: **Go to Manuscript 2 – Salt Creek *in situ* Toxicity Testing Program (next manuscript)**

Return to Start of Report (for Table of Contents)

Links to Supporting Data Files